JPL NO. 9950-523

DRL-73/SE-8

DOE/JPL-955055-81/6
Distribution Category UC-63

(NASA-CR-164164) SILICON SOLAR CELL PROCESS DEVELOPMENT, FABRICATION AND ANALYSIS Final Report (Spectrolab, Inc.) 75 p HC A04/MF A01 CSCL 10A

N81-21541

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G3/44 41994

SILICON SOLAR CELL PROCESS DEVELOPMENT, FABRICATION AND ANALYSIS

Final Report

CDRL #6

JPL Contract No. 955055

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March 9, 1981

The JPL Low-Cost Silicon Solar Array Project is sponsored by the U.S. Department of Energy and forms part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory, California Institute of Technology by agreement between NASA and DOE.

ABSTRACT

Solar cells have been fabricated from unconventional silicon materials in the second and final phase of the contract.

In the most recent period of work, EFG, Web, Hem, and Continuous CZ silicon materials were fabricated into solar cells, measured and analyzed.

Current-voltage measurements under AM1 conditions, in addition to those under AM0 conditions, were introduced in Phase II. Several low-cost fabrication steps were included in that phase.

Both Hem and Continuous CZ silicon were found to be superior to what had been provided in Phase I. Correlation between quality of starting materials and cell conversion efficiency was observed for Hem-grown silicon. Correlation between position in the crystal growth sequence and cell quality was observed for Continuous CZ.

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1.0 INTRODUCTION

The goal of this contract has been to conduct a silicon solar cell process development, fabrication and analysis program. The effort being directed toward the evaluation of the solar cell potential of unconventional silicon sheets of interest to the Large Area Silicon Sheet Task of the Low-Cost Solar Array Project. What has been required has been the fabrication of a statistically significant number of solar cells using standard and reproducible processes and reliable testing of them using standardized measurement equipment and techniques. In addition, to investigate, develop and utilize technologies appropriate and necessary for improving the efficiency of solar cells made from these silicon sheets using a standard process as the baseline starting point. The goal for solar efficiency is 12% Air Mass Zero (AM0), measured at 28°C minimum.

In this report we shall provide a review of the control program, baseline processing, various optimization processes, the measurement systems/procedures and a brief description of the unconventional silicon materials in the program. We shall then report on results obtained since the last published report. This will then be followed by a brief review of results in Phase I and Phase II of the contract.

2.0 TECHNICAL DISCUSSION

A number of diverse silicon materials have been made into solar cells by both conventional and optimized processing methods during the period of this contract. In order to provide a reasonable amount of reproducibility within each material group of cells, a specific control program was mandated. It was believed that this control program would minimize the occurrence of wafer contamination from extrinsic sources. Because elevated temperatures are used and since contamination is sustained via a thermal pathway, emphasis was given to reduction of contamination before and during the impurity diffusion process.

2.1 CONTROL PROGRAM

Quartz diffusion tubes dedicated to the program were used throughout the study. After cleaning a diffusion tube the tubes were then used in processing control wafers into solar cells. The finished solar cells were measured for I-V on a solar simulator and if the results were satisfactory the tube was then considered contamination-free and used for thermal diffusion of one of the unconventional materials into solar cells. In the event the control cells were found not to be satisfactory, the diffusion tube was again cleaned and the process repeated until suitable control cells were obtained. At no time were different sheet materials run together in the same diffusion tube, and only after the above control procedure had been satisfactorily completed would a tube be used for a different sheet material.

During processing of the sheet materials control cells were included. Within the diffusion tube eight control wafers were

positioned on the quartz diffusion tube such that every unconventional silicon wafer had a control wafer neighbor. Control wafers were also positioned at the front and back of the wafer assembly on the diffusion boat.

These same control wafers accompanied the lot throughout fabrication and measurement. Such a procedure also allowed a means of comparison and some indication of processing fidelity.

2.2 PROCESSING FORMAT

The unconventional silicon material was supplied by the Jet Propulsion Laboratory. CZ, p-type, $\sim 2\Omega$ cm silicon control wafers were produced in Spectrolab's crystal growing and cutting facilities. After cutting of the material into slices both the front and back of the slices were etched sufficiently to remove saw damage. This was not required for the material that had been grown in sheet form. In the latter case various cleaning methods, including acid etch, were used to remove surface stains that might have been present. The slices, or ribbons, were then diced to their planar wafer dimensions on a Tempress saw.

After cleaning to remove both organic and metallic surface impurities, the wafers were loaded onto a clean quartz boat and placed within a three-inch diameter quartz diffusion tube maintained at the diffusion temperature (850°C) by a Thermco furnace. The diffusion schedule was arranged such that the wafers were loaded and in the furnace within an hour of the wafer cleaning.

A three step diffusion procedure was used: warmup (nitrogen flow), Pre-dep (phosphine, nitrogen, oxygen flow), and drive (oxygen and nitrogen flow). These conditions were expected to result in a

phosphorous surface concentration in excess of 10^{20} cm^{-3} and pn junction depth of $\sim .35\mu m$. Following the diffusion drive the boat was removed from the furnace and allowed to cool in air.

After diffusion and cool the wafers were immersed in an HF solution to remove the thermal oxide. Sheet rho was then measured on a four point probe to obtain an estimate of junction depth. The fronts of the wafers were then masked and the wafers passed through an acid shower. This was used in order to remove the n-diffused region on the back surface of the wafers. After removal of the etch mask the wafers were cleaned in various solutions, loaded in an evaporation mask and holder and placed in the chamber of a high vacuum system. Using an electron-beam heating source, thin layers of titanium, palladium and silver were deposited on the wafers in a contact pattern defined by the masks. After removal from the evaporation system and masks, the wafers were sintered in a hydrogen atmosphere to minimize contact resistance. The cells were then placed in an electron-beam evaporator where an AR film of Ta_2O_5 was deposited.

In the next and final procedure the wafers were masked with an organic film over top and bottom surfaces. In this state the cells were immersed in a solution to remove any metal or other undesirable contaminant that could cause low shunt resistance at the cell edges. The cells were cleaned and made ready for measurement.

2.3 MEASUREMENT SYSTEMS

2.3.1 Illuminated Current-Voltage

This system is shown schematically in Figure 1. The Spectrosun Solar Simulator is adjusted to produce an AM0 spectrum and intensity. Temperature and intensity calibration for each group of

I-V measurements is made by adjusting water bath temperature and simulator intensity while monitoring these parameters with the #1037 balloon-flown solar cell standard.

The cell test fixture is water cooled, uses a vacuum hold-down and has spring-loaded voltage probes and spring-loaded current probes for cell top contact. The fixture itself makes electrical contact with the bottom of the cell. A Spectrolab Model D-550 electronic load is used in series with the cell under test. Both short circuit current and open circuit voltage are measured by means of a 4½ digit Dana Digital Voltmeter. The I-V curve is generated by the electronic load and recorded on a Hewlett-Packard X-Y Recorder.

AM1 measurements are obtained by introduction of a constant temperature Pyrex-water filter into the light path between the Xenon source and the water-cooled test fixture. After insertion of the filter into the system the light source is adjusted using a standard solar cell, #1039, that has been calibrated to Air Mass One. The filter is tilted slightly from the horizontal to prevent reflection of the radiation back into the source.

2.3.2 Spectral Response

This system consists essentially of a water-cooled test fixture enclosed within a light box. A broad spectrum, high intensity light source impinges upon a filter contained within a filter wheel. Narrow-band radiation is transmitted through the filter and onto the top surface of the cell under test. The short circuit current is measured by amplifying the voltage across a low value precision resistor and reading the amplified voltage on a Dana 5-digit Digital Voltmeter.

The filter wheel consists of thirteen narrow band-pass filters incremented across the spectrum from .4 to 1.05 μm.

Irradiance at the cell surface for each of the thirteen filter positions is measured using a calibrated solar cell. Based upon the irradiance and output of cell under test the relative response can be determined for the cell under test at each of the thirteen wavelengths.

2.3.3 Dark Current-Voltage

Dark current, forward and reverse, is measured on a system consisting of a high resolution constant current supply, a light shielded brass test fixture, and two 5-digit Dana Digital Voltmeters. Measurements are made point-by-point using voltage as the independent variable.

2.3.4 Resistivity

Wafer resistivities are measured by means of a four point, in-line probe and micrometer thickness gauge. The in-line probe is also used to measure sheet resistance after diffusion.

2.4 UNCONVENTIONAL SILICON MATERIALS

2.4.1 Wacker Silso

Wacker Silso polycrystalline silicon is a product of the Wacker Siltronic Corporation. It is produced by casting molten silicon into rectangular blocks. Casting is controlled so as to promote columnar grain growth such that grains grow perpendicular to the plane of the finished cut sheet. The casting is sawed into sheets of square form. This material was used for solar cell fabrication in Phase I of the contract.

2.4.2 Ribbon-to-Ribbon (RTR) Silicon

This material is a product of Motorola and is produced by a process that deposits silicon upon strips of substrate material by CVD. The resultant silicon strips are then laser or electron beam scanned to promote grain growth from the extremely small grains obtained during CVD deposition. A phosphorous gettering step completes the process. The strips used in this contract were about an inch in width and 12 inches in length. This material was used in Phase I of the contract.

2.4.3 Edge-Defined Film Fed Growth (EFG) Silicon

This polycrystalline silicon is produced by Mobil-Tyco. Silicon strips are pulled through dies (SiC) from the melt with widths in excess of two inches and lengths greater than four inches. The finished sheet has a smooth, somewhat rippled surface. Both rf heated and resistance heated systems have been used in the production of the sheet material, only resistance heated material was used in Phase II of the contract.

2.4.4 Dendritic Silicon Sheet (Web)

Web silicon is produced for the program by Westinghouse Research and Development Center. This sheet material is manufactured by supporting a silicon meniscus between two dendrite rails which are slowly lifted out of the melt. The silicon solidifies as it is lifted and this forms a continuous sheet of material. The surface of the drawn filament, or ribbon, is in the 111 plane. Thickness of the filament is well controlled and width is determined by the spacing of the dendrite rails. Web material used in the program was generally in widths of about one inch while thicknesses ranged from 4 mils up to 12 mils.

2.4.5 Heat Exchange Method (Hem) Silicon

This material is produced by Crystal Systems, Inc. In this method a seed crystal is placed at the bottom of an insulated chamber. An inert gas is used as a heat exchanger for the seed and precludes its loss when molten silicon is injected into the chamber.

The freeze boundary of the cooling silicon proceeds out from the seed, generally with growth of a single crystal. Directional solidification, proceeding at a very low rate (depending upon how well heat exchange is controlled), will cause those materials having low segregation coefficients to segregate and thus be moved along with the freeze boundary toward the outer surfaces of the boule. The boule is generally formed in a rectangular shape. Rectangular slices are then cut from the boule.

2.4.6 Continuous CZ Ingots

This material is produced by the Kayex Corporation. In the conventional CZ method a single crystal is pulled from the melt contained in a quartz crucible. The pull of one crystal completes the operation and the crucible is treated as an expendable at a rate of one crucible per pulled crystal. In the continuous CZ method several crystals are pulled in sequence from a single crucible. The melt in the crucible is replenished after each pull. In Phase I of this contract, material from a five crystal pull run was processed into cells while in Phase II material from a nine crystal pull was processed into solar cells.

2.4.7 Silicon on Ceramic (SOC)

This method of producing unconventional silicon has been developed at the Honeywell Corporate Research Center. Slotted

ceramic substrates coated on one side are either dipped into or skimmed over molten silicon, leaving a coating of polycrystalline silicon on the ceramic. Although this material was received under Phase I and Phase II, cell fabrication and measurement were not completed within the time and funding limits for the contract.

2.5 PROCESS OPTIMIZATION

Process optimization in this program is proposed in the sense of both general and specific methods that might be expected to enhance device performance over and above what was achieved by the baseline process. Optimization procedures were limited, however, by the large number of materials studied and the size of the program. With this in mind a number of optimization steps were used for each of the silicon materials in the program.

2.5.1 Texturization

This process modification has two functions. The primary one is the reduction of surface reflections while the second is to increase absorption in the immediate region of the junction.

Surface texturization is the result of directionally selective etching of a wafer surface that leaves a matrix of pyramids at the surface. (In Figure 2 we show a photograph of a typical texturized surface.) This matrix promotes transmission of reflected primary rays. Solar cell surfaces that have been both texturized and coated with an antireflecting film appear mattelike to the observer. Since the index of refraction of silicon is high, and since the pyramids present a surface of about 45° to the normal incidence, normal rays are refracted away from the normal to the wafer plane. The result of this

refracted path for the transmitted radiation is a longer path of light with wafer depth and hence enhanced absorption near the junction.

Texturization is most effective for (100) silicon and ineffective for (111) silicon. Since dendritic web silicon is grown with a (111) surface this optimization procedure was not used on that material. For the polycrystalline material the effectiveness of texturization varied according to the orientation of individual grains.

2.5.2 Back Surface Field

In this procedure a P^+ region is processed onto the back side of the wafer. This P^+ region serves a number of purposes. It creates an electrostatic reflector in the lower base region and reduces contact resistance. The electrostatic reflecting properties should increase short circuit current and reduce dark currents that arise by recombination at the back surface. This should, in turn, increase open circuit voltages. In addition to the obvious requirement that the electric field generated by the $P\ P^+$ configuration be of a sufficient magnitude the distance from the junction to the $P\ P^+$ boundary region, vis a vis the minority carrier diffusion length, must be within certain limits. For a given χ_J to $P\ P^+$ distance, a threshold minority carrier diffusion length exists to observe the effect. Therefore, materials with short minority carrier diffusion lengths cannot be expected to be enhanced by a back surface field. One could, of course, speak of a threshold χ_J to $P\ P^+$ distance for a given L_D.

2.5.3 Junction Depth

Historically, junctions of space solar cells have followed a course of decreasing depths. An observer could speculate that

this has been the result of a somewhat gradual realization that photons absorbed above the junction are wasted. Shallower junctions have required heavier doping in the top layer and improved contact systems because of the increased sheet resistance that accompanies the shallow junction. Improved diffusion methods have also accompanied the shallower junctions providing a somewhat higher minority carrier lifetime in the top layer. Recently, efforts at reducing surface recombination velocities on silicon solar cells have shown some degree of success.

Shallow junctions are of greater efficacy at AM0 because of the relative portion of that spectrum in the blue and violet. Though it is less of a factor for cells to be employed at terrestrial sites, it is still possible to ehhance collection efficiency of terrestrial cells by means of shallow junctions. Shallow junctions, however, increase the risk of junction leakage and result in lower production yields. With these caveats in mind shallow junctions were utilized in several optimized processing runs.

2.5.4 Gettering

It is well known that certain types of "gettering" can enhance performance of silicon devices. Gettering is believed to result because of an out-diffusion and trapping of various secondary impurities at gettering sites. The type of secondary impurities that combine with lattice structure defects to produce recombination centers are in most cases fast diffusers and are trapped at regions of structural damage and strain. Various experimental work has shown that phosphorous precipitates generate high strain, dislocation tangles, etc. This highly damaged region in the top layer of the silicon device leads to very short minority carrier

lifetimes in volume immediate to the surface. At the same time, however, it tends to clean up the rest of the device, especially the junction region.

Evidence for the effect of secondary impurities on device performance has been shown by, amongst others, experiments of Goetzberger and Shockley[2]. Specific evidence for mechanisms in the junction region have been described in the SEM-EBIC experiments of Varker and Ravi[3]. Murarka[4] has identified the phosphorous gettering action on trace impurities of gold using neutron activation analysis. The latter work shows conclusive evidence that the gettered specie (gold) is trapped within the surface region of the precipitates and not within the phosphorous glass.

2.6 PHASE II

A number of changes were made in the program going from Phase I to Phase II. The first of these changes was I-V measurement at AM1 as well as at AM0, for about 20% of the cells. This was done to provide measurements more meaningful for terrestrial application, and to provide empirical relationships between AM0 and AM1 efficiencies for the cells fabricated in the program. A second change was the use of processes that could be considered low cost, as opposed to the methods of Phase I that were based upon aerospace manufacturing processes. A third change was a somewhat more general use of the cell areas greater than 2 cm x 2 cm. Finally, a record was made of the steps in the processing where cell breakage occurred. This was suggested as a means of determining any critical breakage points in the processing for a specific material.

2.7 RESULTS

2.7.1 Westinghouse Web

In this section we report results for three lots of solar cells fabricated on dendritic web-grown silicon utilizing processes intended to enhance conversion efficiency. In the first of these lots, Web0-1, cells were 2 cm x 4 cm and had back surface field processing. Results obtained from illuminated I-V at AM0 and AM1 are presented in Table 1.

In a second lot, Web0-2, also with BSF, cells were made in a 2 cm x 2 cm configuration. Results obtained for illuminated I-V measured at AM0 and AM1 are shown in Table 3. It is apparent that the latter BSF were more effective in improving cell efficiency than in the case of lot Web0-1. This can be attributed to insufficient heating of the substrate during the high temperature anneal following deposition of aluminum paste for the BSF. The warmup of the wafers is dependent upon furnace temperature, boat configuration and wafer size. To produce the back surface field the wafer temperature must surpass the Al-Si eutectic temperature over the whole of the wafer area. In Figure 3 we show those cells with BSF having the highest efficiency of the cells in each dendritic web strip. Other noteworthy differences between the two lots can be seen in the open circuit voltages. In Web0-1 we find V_{oc} of the order of 530 mV and 545 mV for 9 Ω-cm and 3 Ω-cm cells as compared with 555 to 585 for the 13 Ω-cm web materials in lot Web0-2. Another factor of importance in comparing these two lots is the difference in wafer thicknesses. The lesser thickness in Web0-2 cells would be expected to enhance the effect of the back surface field. Diffusion length would of course be expected to play a noticeable role in the effects promoted by wafer thickness.

A third and final web optimization lot, WebO-3, was made using a shallow junction. Measurements for the completed cells are given in Table 5. Cell size used in this lot was 2 cm x 4 cm. Spectral rèsponse data has been plotted for a number of cells in Figures 4 and 5. Blue response is equivalent for the Web and CZ cells, but a rather extensive divergence for red response is seen between the two materials. This suggests considerable differences in minority carrier diffusion lengths between the two materials.

We examine this difference by calculation of the effective diffusion lengths from spectral response measurements[5].

S/N	L_D	γ
X-1	223 μm	.9997
X-5	209	.9995
191-1	79	.9993
187-1	71	.9995
171-1	79	.9995
171-3	74	.9994

2.7.2 Mobil-Tyco EFG

Lot EFGO-2 was intended as an optimization of cell characteristics by means of a back surface field. Application of the back surface field structure to the cells was by screen printing of aluminum paste followed by a high temperature anneal for a brief period (spike anneal). Processing of the cells in this lot met with a continuous series of misfortune. Breakage for the cells in the lot was widespread. Six of ten control cells and three of about thirty-five EFG cells were unbroken. As can be seen in the tables for this lot (Tables 7 and 8) breakage occurred

at most steps of the cell processing. Although breakage has not been found unusual for the EFG material, results in this lot indicate a high degree of fragility. Breakage losses were also unusually high for the control cells, however. In comparing losses in this present lot with those of previous lots, one must conclude that faulty processing must account for a large share of the breakage. Cell data for the lot is given in the tables. Illuminated I-V characteristics are lower than expected for both the EFG cells and control cells.

2.7.3 Crystal Systems Hem

Silicon wafers by the heat exchange method have been fabricated into solar cells by methods intended to improve the solar conversion efficiency over the cells fabricated by the baseline method. Some of these methods are considered to be low cost. A base etch was used in place of the usual conventional acid etch for removal of saw damage and control of wafer thickness. A back surface field has been applied to the cells for increased V_{oc} and I_{sc}.

Lot Hem0-2 was fabricated to determine the effectiveness of the back surface field on this material from a specific Hem crystal (342C) and also to see what, if any, enhancement could be expected by using a thinner wafer thickness. The lot consisted of 9 mil cells made using back surface field cells, 9 mil cells made by the baseline method, and 5 mil cells made using back surface fields.

Results for the lot are given in Tables 9 and 10.

Comparison of I_{sc} between baseline and back surface field processing indicates a definite enhancement for the latter cells. In the case of the control cells V_{oc} enhancement is also observed although this is not the case for the Hem cells. Lack of V_{oc}

enhancement for the Hem cells is not too surprising, however, since resistivity was determined to be less than 1 Ω-cm.

In Figure 6 we display data for average values of the spectral response from 6 μm to 1.05 μm for the 5 mil-BSF, 9 mil-BSF and 9 mil-baseline. One observes the current enhancement of the cells having back surface fields. In Figure 7, percent enhancement of 9 mil BSF cells over 9 mil baseline cells is shown (average values). As one would expect, enhancement is greatly increased for current generated by photons absorbed deeper in the base region of the cell (and hence the path described by distance from absorption site to BSF + distance from BSF to junction is less for longer λ photons, on average).

L measured from spectral response on the following baseline cells in Hem0-2 is given below[5].

S/N	L	γ
C-7	200	.9987
14	100	.9998
15	80	.9992
12	70	.9995

Diffusion length calculations suggest variation in Hem material within crystal sections. (Exact location of section in crystal 342C was not noted by processing personnel.)

Two lots of cells were fabricated from the Hem silicon to determine the effect of impurity gettering on this material and what this might do insofar as efficiency optimization is concerned.

In the first of these lots, Hem0-3, the wafers were phosphorous diffused in the usual manner. The wafers were then etched

sufficiently to remove the diffused n layer. The pre-diffusion clean was repeated and the wafers were again diffused. Processing was continued by the baseline method and the finished cells were measured.

In the second lot, HemO-4, the processing used in HemO-3 was duplicated with the exception that the diffusion drive time in the first diffusion was extended by a factor of three.

Results for both of these lots are given in Tables 11, 12, 13 & 14.

In Figures 8, 9 and 10 we show a histogram of the crystals for the various I-V parameters in the three lots. One may draw several conclusions from these figures. The first of these is that cells made from silicon material in crystal 349 had degraded properties in the runs with the extra gettering step. The results for cells from material in crystal 342 indicate little or no change. Results for cells from material in crystal 314 indicate a definite improvement, especially evident in the HemO-4 results.

A disturbing feature of these results is the high V_{oc} for this material (1.4 Ω-cm). One would expect a maximum of 590 for such resistivity.

As a specific group, cells made from crystal 349 without an added diffusion step (gettering) had the best conversion efficiencies.

Crystals 349 and 342, with resistivities in the range of .4 to .8 Ω-cm, were grown from high purity melt stock. Crystal 314, with resistivity of 1.4 Ω-cm, was grown from float zone remelt stock. One can account for the higher open circuit voltages of the former by the lower resistivities. The reduced short circuit

currents and efficiencies obtained for solar cells fabricated on crystal 314 material could result from the increased secondary impurities one would expect to be contained in float zone remelt stock.

2.7.4 Kayex - Continuous CZ

Material for solar cell fabrication in Phase II of the contract came from run 62 of the Kayex effort. Nine crystals were pulled from a single crucible in run 62. The crystals were of the order of five to six inches in diameter and were sliced to give representative portions of the top, middle, and bottom sections of each crystal.

Two baseline runs were made on this material. Since this was CZ material the primary interest here was to determine how the cells from this material compared with conventional CZ grown material, how cells fabricated from top, middle and bottom sections of a crystal compared and finally how cells from one crystal compared with cells from other crystals in the pull sequence.

Illuminated I-V results for the first baseline run, HamcB-1, are given in Table 15. A and B prefixes denote cells from slice A and slice B. Both slices are from the top section of crystal #1 in Kayex run 62. Dark current data are given in Table 16 and spectral response data are given in Table 17. Comparing the Kayex CZ with the control CZ cells one observes a higher solar conversion efficiency for the latter. In Figure 11 a comparison of spectral response is made between the cells with highest efficiency in slice A, slice B and the CZ control cells. This group of curves implies a slightly greater minority carrier diffusion length for the control CZ silicon.

In the second baseline run, HamcB-2, cells were fabricated from slices cut from five different crystals in Kayex run Number 62. Data for illuminated I-V, spectral response and dark current are presented in Tables 18, 19, and 20, respectively. A modification in this run was the use of NaOH (30%) etchant in place of the usual acid etch to remove saw damage and thin the wafers to 9 mils, but without surface texturizing.

In Figure 12 the distribution for conversion efficiency is plotted for the Kayex CZ cells and for the control cells. The distribution for both groups is similar. The Kayex cells are identified as to the location they occupied in the crystals; top, middle, or bottom. Distributions for efficiency are plotted for the cells and separated by crystal source. Control cell efficiencies are clustered about 11.5% whereas the Kayex CZ cells are clustered about 11%. Cells from bottom sections of crystals 7 and 9 represent the lowest efficiencies for the Kayex group. Three of the four low efficiency cells are polycrystalline while the cell with the lowest efficiency had arrays of deep etch pits across its surface.

In Figure 13 spectral response data for a number of the cells has been plotted. Cells fabricated from top sections of the crystals group about the control cell C-1. The bottom of crystal number 1, middle of crystal nine, bottom of crystal number 7 and bottom of crystal number 9 have reduced spectral response, with the bottom of number 9 occupying the position of lowest response.

Such an order is not unexpected since the secondary impurities would be segregated out of the growing crystal and into the liquid silicon remaining in the crucible. The density of impurities remaining in the crucible would increase with growth causing the concentration of impurities to be higher at the bottom end

of the crystal. With the addition of more silicon before the next crystal pull, the impurities would be diluted hence the top of the next crystal should be "cleaner" than the bottom of the previous crystal. Going from the first crystal to the ninth crystal one would expect a gradual increase in impurities in the melt. An increase in the concentration of secondary impurities in the crystal would reduce the minority carrier diffusion length and this would be apparent in a reduced long wavelength spectral response. In Figure 14 the percent reduction in spectral response for the various crystal sections is shown, at .8 μm and at .9 μm, where the average response for cells from top sections of the crystals serves as the benchmark value.

Although there is evidence of reduced diffusion length as growth proceeds from beginning to end, the effect on conversion efficiency is apparent, yet not large.

In the next fabrication lot the cells were made incorporating a back surface field. Illuminated I-V data for this run, HamcO-1, are given in Table 21. Spectral response and dark current data are given in Tables 22 and 23, respectively. In Figure 15 open circuit voltage and short circuit current are plotted for the cells in this run. Baseline values, derived from runs HamcB-1 and HamcB-2, are given for comparison. There is a general enhancement in both open circuit voltage and short circuit current for both the top and middle section cells with the greater enhancement for the former. For the bottom cells there is some short circuit current enhancement but none for open circuit voltage. Cells below the baseline had shunting and/or series resistance indications in their illuminated I-V curves.

In Figure 16 conversion efficiency at AM0 is plotted for run HamcO-1. The enhancement by the BSF is in evidence here with

greatest percentage enhancement for cells from top sections and least enhancement for cells from bottom sections. In the final figure for this section, Figure 17, spectral response is presented for several cells having the best efficiency in their respective group. From this plot one observes the degree of enhancement provided by the back surface field for a given cell thickness and minority carrier diffusion length. The greater enhancement can be easily seen for the longer diffusion length material.

2.8 AIR MASS ONE I-V CHARACTERISTICS

As stated in Section 2.6, I-V measurements at AM1 were instituted in Phase II of the contract for 20% of the cells. This was done to obtain more relevance for terrestrial application and to determine an empirical relation between AM0 and AM1 characteristics for cells of this type. AM1 measurements were made on the Spectrolab solar simulator (X-25) with a Pyrex water filter in the optical path and calibrated against a standard cell, #1039, traceable to NASA standards. Results are presented below for η_{AM0}/η_{AM1}. On several occasions the efficiency ratio was found to diverge sharply from $\sim$1.17. Generally, this could be traced to measurement or calculation error.

Results for efficiency ratio measurements are given below.

	N	$\overline{R}$
Hem	29	1.17
Web	36	1.18
Kayex	24	1.18
Control CZ	41	1.17
Composite	130	1.17

where N = number of cells

$\overline{R}$ = average value of R

$R = \eta_{AM1}/\eta_{AM0}$

2.9 CONCLUSIONS

Cells fabricated from Web silicon were somewhat broad in their distribution of efficiencies. This would be expected since the web material was itself rather varied in both resistivity and minority carrier lifetime. The back surface field was found to be effective in enhancing the open circuit voltage, as in lot Web0-2 where 12 Ω-cm web material had open circuit voltages of 580 mv. Spectral response measurements have shown the wide differences in diffusion length between the CZ control material and some of the web material used in these few lots as they have also shown differences in the diffusion length from one web strip to the other.

For the Hem material we have found a variation in cells fabricated from different crystals. The crystals we have used represent but a small fraction of the boule so what we have found must be qualified by that condition. As would be expected the "cleaner" the starting material the higher the cell efficiency. Some of the Hem material was apparently equivalent to the CZ material used for control cells. The low resistivity material, in some instances, when fabricated into cells had open circuit voltages greater than 600 mv and with BSF some enhancement in current was observed. Gettering did not appear to offer enhancement of the cell efficiencies.

The continuous CZ material was found to produce reasonably good cells with some fall-off in efficiency from the top to the bottom of the crystals. The fall-off in diffusion length from the first to the last crystal was obvious from the spectral response curves, however its effect upon conversion efficiencies was not so apparent. Only when back surface fields were applied was the reduced diffusion length significant as a factor that attenuated the effect of the back surface field.

3.0 REVIEW OF PHASE II

Phase II has followed a path very similar to Phase I. In essence much of the work was a repeat with some variations. Most of the size etching was done using NaOH etchant in place of the usual acid etchant. This was a part of the low cost thrust. It had limited significance on the outcome of the various lots.

Screen printed contacts were tried on cells fabricated from EFG material but the effect was to degrade the cell performance. It became obvious that screen printed contacts could be a program in its own right since several of the materials could not be printed without some very specific fixtures and problems.

The most significant outcome in this phase would have to be associated with the Hem material and the continuous CZ silicon. In the case of the former, some Hem crystals were found to provide cells with performance on a par with CZ control cells and showed a dependence upon the quality of silicon material being processed by the heat exchange method. It did not, and could not, show uniformity or the lack of uniformity in the Hem boule because only small sections of each crystal were provided.

In the case of the continuous CZ material, considerable improvement was evident in the Phase II material over the Phase I material. In Phase I, with fewer and smaller crystals pulled, only top sections were single crystalline and only those produced quality cells. The Phase II product, however, consisted of more and larger crystals in a single run, and most parts of the crystals had the potential for quality solar cells. Only in bottom sections was optimization limited.

The EFG material was not better than the resistance heated source material in Phase I. It would have been more productive to have had some of the material developed with controlled CO_x atmospheres and reported on by Mobil-Tyco.

4.0 SUMMARY AND CONCLUSIONS

In this section we provide a table containing maximum conversion efficiencies for each material throughout Phase I and Phase II of the program. Data are displayed graphically in Figure 18.

We note from this table that of the expressed Phase I contract goal of 12% AM0 at 28°C, three of the materials reached or surpassed the goal, namely: dendritic web, Hem, and continuous CZ.

LIST OF CELLS HAVING HIGHEST EFFICIENCY FOR THEIR MATERIAL GROUP

Material	η% (AM0) (28°C)	J_{sc} mA cm^{-2}	V_{oc} (mV)	FF	Lot	S/N	Comment
RTR	7.2	23.6	559	.74	RTR-2	5	Baseline
Control*	11.6	36.3	588	.73		C-7	
EFG-RF	9.8	31.3	567	.75	EFG-3	46	Baseline
Control*	8.9	35.5	563	.60		C-5	
EFG-RH	8.4	29.0	537	.73	EFGB-1	D	Baseline
Control*	11.9	35.8	586	.77		6	
Wacker Silso	10.6	33.5	554	.77	W-4	4	Baseline
Control*	12.5	35.5	598	.79		2	
Web	12.0	37.3	579	.75	Web-5	6	BSF
Control*	13.0	37.0	596	.80		H	BSF
Hem	12.3	34.8	605	.790	HemB-1	349 S2 E1	Baseline
Control*	12.1	35.8	589	.778		C-3	
Cont. CZ	12.6	36.8	602	.770	HamcO-1	9T2	BSF
Control*	All Shunted						

*Control cell with highest η in the same lot.

The RTR and EFG materials used in this contract are now obsolete. Claims by both sources of these materials indicate that considerable improvement in quality has been attained. The Wacker material

could probably be brought to higher efficiencies than reported here by using thinner cells in conjunction with back surface fields. There was a noticeable drop-off in efficiency at the corners of the Wacker sheet due to either reduced grain size or oblique grain boundaries.

The web material would appear to have considerable potential for high quality cells. The ability to control the sheet thickness as well as resistivity and lifetime would make this material a formidable contender in the high efficiency cell class.

The heat exchange method has shown itself to be capable of producing quality solar cells. This is especially true when clean polysilicon is used as the starting material. How uniform the quality is throughout the grown crystal has not been shown. The method also appears appropriate for growth of solar material from starting material that could only be classed below semiconductor grade polysilicon.

The continuous CZ method employed to produce some of the material in the contract does appear to have considerable potential. The consistent results from top to bottom and crystal to crystal and the overall improvement from Phase I material to Phase II material supports this outlook.

5.0 ACKNOWLEDGEMENTS

The author wishes to acknowledge the support of Mr. Dennis Dionne throughout Phase I and Phase II of the contract, of Mrs. Emily Castorena in part of Phase I and Phase II and of Dr. Lincoln Fajardo in part of Phase II of the contract.

He appreciates the patience and forbearance shown by Dr. Taher Daud, Mr. Francis Uno, Ms. Catherine Dumas, Ms. Sandra Hyland and Dr. James Liu, of the Jet Propulsion Laboratory. Their understanding of the difficulties involved, especially in the zero slope beginning of Phase I, has been heroic.

Finally, to Mrs. Linda Stone my thanks and respect for preparation of the manuscript and her patience in making numerous corrections in copy, tables and figures.

6.0 REFERENCES

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(2) A. Goetzberger and W. Shockley, "Metal Precipitates in Silicon PN Junctions," JAP 31 (1960) 1821.

(3) C. Varker and K. Ravi, "Oxidation-Induced Stacking Faults in Silicon. II Electrical Effects in PN Diodes," JAP, 45 (1974) 272.

(4) S. Murarka, "A Study of the Phosphorous Gettering of Gold in Silicon by Use of Neutron Activation Analysis," J. Electroch. Soc. 123 (1976) 765.

(5) J. A. Minahan, Quarterly Progress Report for Period ending December 31, 1979, JPL Contract #955055.

7.0 TABLES

Table 1

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

WEB01

CELL NAME	1	2	3	4	5	6	7
AREA (CM2)	4.000	6.000	6.000	6.000	6.000	4.000	6.000
THICK (CM)	.022	.022	.022	.022	.024	.022	.022
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	58.010	57.103	52.118	55.064	.000	56.650	55.517
AMO VOC (MV)	549.000	546.000	544.000	533.000	.000	538.000	.000
AMO ISC (MA)	127.000	245.000	238.000	245.000	.000	126.000	.000
AMO VMP (MV)	444.000	449.000	416.000	426.000	.000	436.000	.000
AMO IMP (MA)	119.000	226.000	214.000	192.000	.000	104.000	.000
AMO FILL FCTR	.758	.759	.688	.626	.000	.669	.000
AMO EFFICIENCY	.098	.125	.110	.101	.000	.084	.000
AM1 VOC (MV)	548.000	545.000	544.000	531.000	.000	537.000	.000
AM1 ISC (MA)	111.000	213.000	206.000	213.000	.000	109.000	.000
AM1 VMP (MV)	453.000	453.000	415.000	425.000	.000	440.000	.000
AM1 IMP (MA)	102.000	196.000	190.000	158.000	.000	68.000	.000
AM1 FILL FCTR	.760	.765	.704	.594	.000	.662	.000
AM1 EFFICIENCY	.116	.148	.131	.112	.000	.097	.000
AM1 EFF/AMO EFF	1.183	1.184	1.198	1.111	.000	1.155	.000
WHEN BROKEN	0	0	0	0	PROBE TEST	0	PRINTING

CELL NAME	8	A	B	C	D	E	F
AREA (CM2)	6.000	6.000	6.000	6.000	6.000	6.000	6.000
THICK (CM)	.022	.025	.025	.025	.025	.025	.025
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	52.931	51.665	55.517	53.704	55.744	55.744	48.946
AMO VOC (MV)	544.000	.000	530.000	528.000	526.000	530.000	526.000
AMO ISC (MA)	242.000	.000	247.000	246.000	251.000	253.000	244.000
AMO VMP (MV)	447.000	.000	427.000	422.000	414.000	426.000	423.000
AMO IMP (MA)	220.000	.000	226.000	226.000	231.000	235.000	226.000
AMO FILL FCTR	.747	.000	.737	.734	.724	.747	.745
AMO EFFICIENCY	.121	.000	.119	.117	.118	.123	.118
AM1 VOC (MV)	543.000	.000	529.000	527.000	525.000	529.000	525.000
AM1 ISC (MA)	209.000	.000	215.000	213.000	218.000	219.000	214.000
AM1 VMP (MV)	445.000	.000	425.000	426.000	419.000	429.000	424.000
AM1 IMP (MA)	189.000	.000	195.000	194.000	199.000	202.000	195.000
AM1 FILL FCTR	.741	.000	.729	.736	.729	.748	.736
AM1 EFFICIENCY	.140	.000	.138	.138	.139	.144	.138
AM1 EFF/AMO EFF	1.157	.000	1.162	1.172	1.180	1.171	1.170
WHEN BROKEN	0	LOADING	CHIPPED	CHIPPED	CHIP/OHMIC	0	CHIPPED

CELL NAME	C	X1	X10	X11	X12	X13	X14
AREA (CM2)	6.000	6.000	4.000	4.000	6.000	4.000	4.000
THICK (CM)	.027	.027	.025	.024	.027	.027	.027
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	58.010	46.226	48.946	49.852	48.492	48.492	45.093
AMO VOC (MV)	531.000	596.000	592.000	586.000	513.000	565.000	608.000
AMO ISC (MA)	253.000	270.000	141.000	140.000	274.000	141.000	144.000
AMO VMP (MV)	408.000	480.000	451.000	465.000	319.000	410.000	495.000
AMO IMP (MA)	230.000	248.000	109.000	93.000	204.000	79.000	124.000
AMO FILL FCTR	.699	.737	.589	.527	.463	.407	.701
AMO EFFICIENCY	.116	.147	.091	.080	.068	.060	.113
AM1 VOC (MV)	530.000	596.000	.000	.000	.000	.000	605.000
AM1 ISC (MA)	220.000	235.000	.000	.000	.000	.000	124.000
AM1 VMP (MV)	416.000	480.000	.000	.000	.000	.000	496.000
AM1 IMP (MA)	198.000	217.000	.000	.000	.000	.000	104.000
AM1 FILL FCTR	.706	.744	.000	.000	.000	.000	.688
AM1 EFFICIENCY	.137	.174	.000	.000	.000	.000	.129
AM1 EFF/AMO EFF	1.168	1.184	.000	.000	.000	.000	1.137
WHEN BROKEN	CHIPPED	0	0	0	0	0	0

Table 1 continued

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

WEB01

CELL NAME	X2	X3	X4	X5	X6	X7	X8
AREA (CM2)	6.000	6.000	6.000	6.000	4.000	4.000	6.000
THICK (CM)	.025	.027	.023	.024	.024	.024	.024
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	51.665	51.212	51.212	50.758	49.852	46.453	49.625
AM0 VOC (MV)	597.000	.000	.000	604.000	596.000	496.000	599.000
AM0 ISC (MA)	259.000	.000	.000	270.000	138.000	140.000	271.000
AM0 VMP (MV)	495.000	.000	.000	502.000	494.000	264.000	459.000
AM0 IMP (MA)	227.000	.000	.000	244.000	130.000	71.000	244.000
AM0 FILL FCTR	.727	.000	.000	.751	.778	.270	.690
AM0 EFFICIENCY	.138	.000	.000	.151	.119	.035	.138
AM1 VOC (MV)	.000	.000	.000	601.000	596.000	.000	598.000
AM1 ISC (MA)	.000	.000	.000	235.000	118.000	.000	236.000
AM1 VMP (MV)	.000	.000	.000	496.000	496.000	.000	466.000
AM1 IMP (MA)	.000	.000	.000	210.000	110.000	.000	210.000
AM1 FILL FCTR	.000	.000	.000	.737	.776	.000	.693
AM1 EFFICIENCY	.000	.000	.000	.174	.136	.000	.163
AM1 EFF/AM0 EFF	.000	.000	.000	1.151	1.149	.000	1.182
WHEN BROKEN	0	TEMP.TEST	TEMP.TEST	0	0	0	0

CELL NAME	X9
AREA (CM2)	4.000
THICK (CM)	.025
B.D.RHO(OHM-CM)	.000
A.D.R-SQR(OHM)	53.704
AM0 VOC (MV)	589.000
AM0 ISC (MA)	146.000
AM0 VMP (MV)	456.000
AM0 IMP (MA)	121.000
AM0 FILL FCTR	.642
AM0 EFFICIENCY	.102
AM1 VOC (MV)	.000
AM1 ISC (MA)	.000
AM1 VMP (MV)	.000
AM1 IMP (MA)	.000
AM1 FILL FCTR	.000
AM1 EFFICIENCY	.000
AM1 EFF/AM0 EFF	.000

Table 2

SPECTRAL SENSITIVITY

WEB01

CELL NAME	1	2	3	4	5	6	7
W.L. (MICRON)							
.41	.125	.150	.146	.160	.000	.127	.000
.45	.283	.340	.328	.356	.000	.298	.000
.50	.394	.451	.437	.456	.000	.391	.000
.55	.428	.493	.480	.505	.000	.425	.000
.60	.462	.521	.525	.524	.000	.431	.000
.65	.472	.562	.556	.560	.000	.459	.000
.70	.487	.580	.570	.578	.000	.476	.000
.75	.508	.614	.601	.606	.000	.507	.000
.80	.521	.632	.615	.592	.000	.489	.000
.85	.488	.602	.583	.588	.000	.478	.000
.90	.451	.536	.520	.556	.000	.479	.000
.95	.338	.415	.396	.407	.000	.339	.000
1.05	.098	.126	.116	.120	.000	.099	.000

Table 2 continued

SPECTRAL SENSITIVITY

WEBO1

CELL NAME	S	A	B	C	D	E	F
W.L. (MICRON)							
.41	.154	.000	.152	.149	.157	.148	.143
.45	.348	.000	.340	.333	.352	.339	.332
.50	.450	.000	.442	.430	.460	.452	.439
.55	.494	.000	.484	.483	.500	.493	.483
.60	.520	.000	.531	.526	.547	.542	.523
.65	.551	.000	.558	.556	.574	.570	.557
.70	.581	.000	.584	.584	.599	.596	.576
.75	.600	.000	.614	.616	.628	.622	.611
.80	.591	.000	.363	.649	.654	.657	.639
.85	.588	.000	.618	.622	.632	.636	.618
.90	.547	.000	.560	.566	.566	.572	.565
.95	.444	.000	.444	.460	.449	.458	.453
1.05	.121	.000	.137	.139	.137	.142	.138

CELL NAME	G	X1	X10	X11	X12	X13	X14
W.L. (MICRON)							
.41	.152	.146	.182	.208	.167	.248	.147
.45	.342	.328	.325	.349	.342	.377	.294
.50	.450	.446	.407	.413	.445	.423	.407
.55	.498	.503	.446	.446	.502	.456	.435
.60	.541	.558	.488	.483	.551	.487	.474
.65	.571	.592	.496	.487	.585	.492	.485
.70	.593	.626	.536	.540	.623	.568	.520
.75	.632	.663	.574	.573	.677	.608	.564
.80	.648	.704	.394	.594	.736	.648	.611
.85	.644	.743	.637	.623	.767	.645	.632
.90	.600	.735	.725	.719	.803	.765	.661
.95	.476	.702	.679	.659	.850	.740	.710
1.05	.148	.305	.357	.347	.436	.411	.353

CELL NAME	X2	X3	X4	X5	X6	X7	X8
W.L. (MICRON)							
.41	.161	.000	.000	.165	.127	.344	.166
.45	.331	.000	.000	.325	.280	.472	.346
.50	.437	.000	.000	.445	.390	.453	.460
.55	.486	.000	.000	.489	.432	.475	.515
.60	.539	.000	.000	.545	.466	.503	.564
.65	.574	.000	.000	.578	.483	.495	.599
.70	.613	.000	.000	.622	.511	.624	.634
.75	.653	.000	.000	.662	.543	.630	.682
.80	.695	.000	.000	.707	.569	.622	.716
.85	.742	.000	.000	.756	.601	.644	.772
.90	.764	.000	.000	.787	.623	.663	.804
.95	.776	.000	.000	.800	.564	.697	.825
1.05	.394	.000	.000	.401	.233	.415	.416

CELL NAME	X9
W.L. (MICRON)	
.41	.160
.45	.316
.50	.408
.55	.444
.60	.483
.65	.491
.70	.518
.75	.557
.80	.584
.85	.622
.90	.674
.95	.664
1.05	.336

Table 3

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

WEB02

CELL NAME	1	1.	10	10.	11	11.	12
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.018	.018	.018	.018	.018	.018	.018
B.D.RHO(OHM-CM)	14.315	14.508	14.206	13.046	14.935	12.063	15.556
A.D.R-SQR(OHM)	49.852	47.586	46.680	47.133	48.266	46.680	47.133
AM0 VOC (MV)	.000	573.000	566.000	562.000	565.000	553.000	585.000
AM0 ISC (MA)	.000	142.000	136.000	140.000	143.000	138.000	141.000
AM0 VMP (MV)	.000	463.000	448.000	442.000	474.000	440.000	469.000
AM0 IMP (MA)	.000	128.000	117.000	130.000	130.000	127.000	131.000
AM0 FILL FCTR	.000	.728	.681	.730	.737	.732	.745
AM0 EFFICIENCY	.000	.110	.097	.106	.114	.103	.114
AM1 VOC (MV)	.000	573.000	.000	561.000	580.000	.000	582.000
AM1 ISC (MA)	.000	123.000	.000	121.000	123.000	.000	123.000
AM1 VMP (MV)	.000	462.000	.000	450.000	468.000	.000	466.000
AM1 IMP (MA)	.000	112.000	.000	111.000	115.000	.000	114.000
AM1 FILL FCTR	.000	.734	.000	.736	.754	.000	.742
AM1 EFFICIENCY	.000	.129	.000	.125	.135	.000	.133
AM1 EFF/AM0 EFF	.000	1.181	.000	1.176	1.182	.000	1.170
WHEN BROKEN	EDGE CLEAN	0	0	0	SPEC.RESP.	0	0

CELL NAME	3	3.	4	4.	5	5.	6
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.018	.018	.016	.010	.018	.018	.018
B.D.RHO(OHM-CM)	13.835	15.374	13.562	12.554	14.214	13.420	14.706
A.D.R-SQR(OHM)	.000	47.813	49.399	47.813	48.039	48.039	.000
AM0 VOC (MV)	.000	.000	580.000	571.000	563.000	576.000	.000
AM0 ISC (MA)	.000	.000	140.000	140.000	144.000	142.000	.000
AM0 VMP (MV)	.000	.000	467.000	457.000	464.000	462.000	.000
AM0 IMP (MA)	.000	.000	130.000	129.000	131.000	130.000	.000
AM0 FILL FCTR	.000	.000	.746	.737	.724	.732	.000
AM0 EFFICIENCY	.000	.000	.112	.109	.112	.111	.000
AM1 VOC (MV)	.000	.000	575.000	566.000	581.000	575.000	.000
AM1 ISC (MA)	.000	.000	121.000	122.000	123.000	122.000	.000
AM1 VMP (MV)	.000	.000	470.000	454.000	466.000	464.000	.000
AM1 IMP (MA)	.000	.000	112.000	112.000	113.000	112.000	.000
AM1 FILL FCTR	.000	.000	.737	.736	.740	.741	.000
AM1 EFFICIENCY	.000	.000	.132	.127	.132	.130	.000
AM1 EFF/AM0 EFF	.000	.000	1.173	1.167	1.177	1.171	.000
WHEN BROKEN	DICING SAW LOADING		0	0	SPEC.RESP.	0	DICING SAW

CELL NAME	6.	7	7.	8	8.	9	9.
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.018	.018	.018	.016	.018	.018	.018
B.D.RHO(OHM-CM)	13.231	14.359	12.997	15.048	13.320	14.097	12.296
A.D.R-SQR(OHM)	47.566	50.305	47.133	47.133	45.773	49.852	45.773
AM0 VOC (MV)	561.000	584.000	575.000	581.000	571.000	582.000	.000
AM0 ISC (MA)	141.000	144.900	127.000	142.000	140.000	139.000	.000
AM0 VMP (MV)	436.000	471.000	461.000	469.000	455.000	471.000	.000
AM0 IMP (MA)	112.000	130.000	116.000	130.000	129.000	127.000	.000
AM0 FILL FCTR	.620	.728	.732	.739	.734	.739	.000
AM0 EFFICIENCY	.091	.113	.099	.113	.108	.111	.000
AM1 VOC (MV)	.000	578.000	.000	579.000	562.000	573.000	.000
AM1 ISC (MA)	.000	124.000	.000	122.000	122.000	121.000	.000
AM1 VMP (MV)	.000	470.000	.000	469.000	455.000	465.000	.000
AM1 IMP (MA)	.000	113.000	.000	112.000	112.000	111.000	.000
AM1 FILL FCTR	.000	.741	.000	.744	.743	.744	.000
AM1 EFFICIENCY	.000	.133	.000	.131	.127	.129	.000
AM1 EFF/AM0 EFF	.000	1.174	.000	1.166	1.175	1.167	.000
WHEN BROKEN	0	0	EDGE ETCH	0	0	0	B.S.F.

Table 3 continued

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

WEB02

CELL NAME	12.	13	13.	14	14.	2	2.
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.018	.018	.019	.018	.019	.018	.018
B.D.RHO(OHM-CM)	12.127	15.209	.000	14.613	.000	13.706	14.291
A.D.R-SQR(OHM)	45.773	.000	.000	48.492	.000	.000	43.507
AM0 VOC (MV)	560.000	.000	.000	.000	.000	.000	563.000
AM0 ISC (MA)	137.000	.000	.000	.000	.000	.000	140.000
AM0 VMP (MV)	447.000	.000	.000	.000	.000	.000	472.000
AM0 IMP (MA)	127.000	.000	.000	.000	.000	.000	129.000
AM0 FILL FCTR	.740	.000	.000	.000	.000	.000	.746
AM0 EFFICIENCY	.105	.000	.000	.000	.000	.000	.113
AM1 VOC (MV)	.000	.000	.000	.000	.000	.000	581.000
AM1 ISC (MA)	.000	.000	.000	.000	.000	.000	122.000
AM1 VMP (MV)	.000	.000	.000	.000	.000	.000	468.000
AM1 IMP (MA)	.000	.000	.000	.000	.000	.000	112.000
AM1 FILL FCTR	.000	.000	.000	.000	.000	.000	.739
AM1 EFFICIENCY	.000	.000	.000	.000	.000	.000	.131
AM1 EFF/AM0 EFF	.000	.000	.000	.000	.000	.000	1.165
WHEN BROKEN	0	V/I PROBE	DICING	V/I PROBE	DICING	SCRIB I.D.	0

CELL NAME	X1	X2	X3	X4	X5	X6	X7
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.023	.023	.023	.023	.023	.023	[illegible]
B.D.RHO(OHM-CM)	2.031	1.948	2.031	1.989	2.196	2.134	2.082
A.D.R-SQR(OHM)	45.773	45.773	48.492	49.399	48.946	46.226	44.414
AM0 VOC (MV)	600.000	603.000	313.000	576.000	598.000	601.000	605.000
AM0 ISC (MA)	147.000	149.000	137.000	146.000	149.000	142.000	152.000
AM0 VMP (MV)	500.000	509.000	178.000	437.000	495.000	498.000	504.000
AM0 IMP (MA)	133.000	137.000	98.000	94.000	127.000	126.000	140.000
AM0 FILL FCTR	.754	.776	.407	.488	.706	.735	.767
AM0 EFFICIENCY	.123	.129	.032	.076	.116	.116	.130
AM1 VOC (MV)	596.000	601.000	.000	.000	.000	.000	602.000
AM1 ISC (MA)	127.000	129.000	.000	.000	.000	.000	131.000
AM1 VMP (MV)	494.000	505.000	.000	.000	.000	.000	502.000
AM1 IMP (MA)	114.000	120.000	.000	.000	.000	.000	122.000
AM1 FILL FCTR	.744	.782	.000	.000	.000	.000	.777
AM1 EFFICIENCY	.141	.151	.000	.000	.000	.000	.153
AM1 EFF/AM0 EFF	1.146	1.176	.000	.000	.000	.000	1.174
WHEN BROKEN	0	0	CELL SLIP	0	0	0	0

CELL NAME	X8
AREA (CM2)	4.000
THICK (CM)	.023
B.D.RHO(OHM-CM)	1.834
A.D.R-SQR(OHM)	46.226
AM0 VOC (MV)	363.000
AM0 ISC (MA)	137.000
AM0 VMP (MV)	203.000
AM0 IMP (MA)	88.000
AM0 FILL FCTR	.359
AM0 EFFICIENCY	.033
AM1 VOC (MV)	.000
AM1 ISC (MA)	.000
AM1 VMP (MV)	.000
AM1 IMP (MA)	.000
AM1 FILL FCTR	.000
AM1 EFFICIENCY	.000
AM1 EFF/AM0 EFF	.000
WHEN BROKEN	CHIP OHMIC

Table 4

SPECTRAL SENSITIVITY

WEB02

CELL NAME	1	1.	10	10.	11	11.	12
W.L. (MICRON)							
.41	.000	.097	.098	.099	.101	.105	.103
.45	.000	.225	.227	.236	.241	.250	.244
.50	.000	.348	.345	.363	.367	.374	.368
.55	.000	.433	.422	.445	.444	.449	.443
.60	.000	.479	.468	.495	.483	.486	.482
.65	.000	.528	.506	.523	.524	.524	.520
.70	.000	.569	.539	.577	.558	.555	.555
.75	.000	.625	.591	.621	.604	.593	.600
.80	.000	.634	.610	.630	.620	.593	.620
.85	.000	.666	.636	.640	.655	.605	.649
.90	.000	.710	.668	.642	.702	.609	.680
.95	.000	.620	.605	.531	.633	.489	.623
1.05	.000	.200	.202	.161	.214	.153	.208

CELL NAME	3	3.	4	4.	5	5.	6
W.L. (MICRON)							
.41	.000	.000	.105	.109	.073	.103	.000
.45	.000	.000	.248	.254	.170	.245	.000
.50	.000	.000	.366	.377	.258	.370	.000
.55	.000	.000	.434	.448	.314	.447	.000
.60	.000	.000	.478	.480	.335	.498	.000
.65	.000	.000	.507	.522	.363	.525	.000
.70	.000	.000	.535	.554	.367	.561	.000
.75	.000	.000	.575	.598	.416	.607	.000
.80	.000	.000	.605	.598	.420	.611	.000
.85	.000	.000	.618	.626	.444	.641	.000
.90	.000	.000	.620	.658	.482	.671	.000
.95	.000	.000	.562	.554	.417	.578	.000
1.05	.000	.000	.187	.173	.140	.165	.000

CELL NAME	6.	7	7.	8	8.	9	9.
W.L. (MICRON)							
.41	.113	.110	.094	.105	.144	.106	.000
.45	.256	.258	.227	.245	.290	.254	.000
.50	.381	.379	.241	.369	.393	.376	.000
.55	.453	.442	.410	.446	.458	.444	.000
.60	.491	.491	.445	.489	.496	.477	.000
.65	.526	.516	.478	.525	.523	.512	.000
.70	.563	.546	.505	.550	.565	.529	.000
.75	.607	.564	.540	.606	.595	.584	.000
.80	.614	.617	.544	.621	.592	.606	.000
.85	.642	.636	.568	.653	.595	.629	.000
.90	.674	.650	.586	.691	.617	.654	.000
.95	.580	.598	.504	.620	.496	.594	.000
1.05	.189	.206	.165	.204	.172	.200	.000

Table 4 continued

SPECTRAL SENSITIVITY

WEB02

CELL NAME	12.	13	13.	14	14.	2	2.
W.L. (MICRON)							
.41	.115	.000	.000	.000	.000	.000	.110
.45	.272	.000	.000	.000	.000	.000	.261
.50	.389	.000	.000	.000	.000	.000	.382
.55	.451	.000	.000	.000	.000	.000	.448
.60	.483	.000	.000	.000	.000	.000	.480
.65	.510	.000	.000	.000	.000	.000	.512
.70	.536	.000	.000	.000	.000	.000	.539
.75	.569	.000	.000	.000	.000	.000	.576
.80	.570	.000	.000	.000	.000	.000	.591
.85	.586	.000	.000	.000	.000	.000	.619
.90	.586	.000	.000	.000	.000	.000	.639
.95	.479	.000	.000	.000	.000	.000	.567
1.05	.151	.000	.000	.000	.000	.000	.200

CELL NAME	X1	X2	X3	X4	X5	X6	X7
W.L. (MICRON)							
.41	.105	.106	.112	.115	.126	.111	.109
.45	.241	.242	.234	.261	.267	.232	.248
.50	.365	.368	.339	.363	.383	.347	.376
.55	.441	.446	.406	.452	.459	.426	.451
.60	.490	.495	.457	.482	.497	.475	.500
.65	.525	.532	.488	.519	.535	.514	.540
.70	.562	.569	.532	.555	.580	.560	.578
.75	.616	.624	.575	.605	.633	.613	.627
.80	.656	.656	.617	.630	.666	.651	.667
.85	.663	.694	.637	.669	.707	.693	.709
.90	.721	.754	.681	.733	.803	.776	.776
.95	.740	.764	.689	.734	.798	.787	.794
1.05	.319	.340	.304	.313	.371	.368	.373

CELL NAME	X8
W.L. (MICRON)	
.41	.217
.45	.310
.50	.359
.55	.415
.60	.465
.65	.490
.70	.617
.75	.628
.80	.626
.85	.666
.9[illegible]	.911
.95	.715
1.05	.369

Table 5

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

WEB03

CELL NAME	175 1	175 3	187 1	191 1	X1	X2	X3
AREA (CM2)	8.000	8.000	8.000	8.000	8.000	8.000	8.000
THICK (CM)	.027	.025	.024	.028	.030	.033	.030
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	111.714	106.275	140.719	101.290	108.315	119.645	97.665
AM0 VOC (MV)	521.000	531.000	525.000	533.000	487.000	554.000	584.000
AM0 ISC (MA)	240.000	214.000	252.000	231.000	294.000	255.000	262.000
AM0 VMP (MV)	377.000	412.000	412.000	406.000	309.000	382.000	469.000
AM0 IMP (MA)	220.000	196.000	234.000	223.000	221.000	189.000	260.000
AM0 FILL FCTR	.663	.718	.729	.735	.477	.511	.772
AM0 EFFICIENCY	.077	.075	.089	.084	.063	.067	.117
AM1 VOC (MV)	523.000	532.000	525.000	533.000	.000	.000	584.000
AM1 ISC (MA)	204.000	182.000	215.000	209.000	.000	.000	242.000
AM1 VMP (MV)	377.000	421.000	416.000	419.000	.000	.000	486.000
AM1 IMP (MA)	190.000	170.000	200.000	192.000	.000	.000	224.000
AM1 FILL FCTR	.671	.739	.737	.722	.000	.000	.770
AM1 EFFICIENCY	.090	.089	.104	.101	.000	.000	.136
AM1 EFF/AM0 EFF	1.166	1.187	1.168	1.202	.000	.000	1.159
WHEN BROKEN		EVAPORATOR				BACKETCH	UNLOADING

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

WEB03

CELL NAME	X4	X5	X6	X7	X8
AREA (CM2)	8.000	8.000	8.000	8.000	8.000
THICK (CM)	.030	.030	.030	.033	.033
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	100.610	94.945	91.773	81.123	79.990
AM0 VOC (MV)	.000	578.000	586.000	567.000	561.000
AM0 ISC (MA)	.000	284.000	167.000	255.000	274.000
AM0 VMP (MV)	.000	463.000	466.000	452.000	444.000
AM0 IMP (MA)	.000	263.000	160.000	223.000	251.000
AM0 FILL FCTR	.000	.742	.710	.697	.725
AM0 EFFICIENCY	.000	.112	.072	.093	.103
AM1 VOC (MV)	.000	578.000	565.000	565.000	563.000
AM1 ISC (MA)	.000	244.000	163.000	220.000	234.000
AM1 VMP (MV)	.000	471.000	489.000	450.000	449.000
AM1 IMP (MA)	.000	226.000	138.000	184.000	213.000
AM1 FILL FCTR	.000	.755	.706	.684	.726
AM1 EFFICIENCY	.000	.133	.084	.106	.120
AM1 EFF/AM0 EFF	.000	1.183	1.174	1.142	1.161
WHEN BROKEN	DICING		EVAPORATOR		

Table 6

SPECTRAL SENSITIVITY

WED03

CELL NAME	X4	X5	X6	X7	X8
W.L. (MICRON)					
.41	.000	.112	.096	.096	.104
.45	.000	.232	.181	.193	.221
.50	.000	.317	.263	.269	.317
.55	.000	.380	.322	.341	.381
.60	.000	.435	.358	.382	.419
.65	.000	.485	.388	.427	.457
.70	.000	.511	.415	.468	.471
.75	.000	.542	.444	.494	.503
.80	.000	.577	.474	.533	.544
.85	.000	.600	.483	.566	.544
.90	.000	.609	.486	.566	.527
.95	.000	.605	.497	.548	.498
1.05	.000	.247	.203	.228	.186

SPECTRAL SENSITIVITY

WED03

CELL NAME	175 1	175 3	187 1	191 1	X1	X2	X3
W.L. (MICRON)							
.41	.095	.083	.107	.093	.124	.112	.113
.45	.207	.172	.217	.187	.262	.246	.236
.50	.298	.245	.311	.272	.334	.321	.325
.55	.354	.308	.369	.345	.410	.376	.401
.60	.387	.350	.411	.386	.454	.425	.449
.65	.417	.382	.435	.416	.496	.457	.475
.70	.432	.404	.456	.437	.522	.488	.5[illegible]3
.75	.451	.419	.464	.458	.550	.522	.521
.80	.466	.420	.478	.470	.577	.562	.547
.85	.456	.410	.473	.468	.609	.577	.572
.90	.409	.376	.428	.421	.614	.580	.566
.95	.324	.285	.320	.322	.608	.573	.554
1.05	.095	.063	.091	.096	.259	.250	.218

Table 7

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

EFG02

CELL NAME	A1	A2	A3	A4	A5	A6	A7
AREA (CM2)	6.450	6.450	6.450	6.450	6.450	6.450	6.450
THICK (CM)	.037	.032	.039	.038	.034	.030	.027
B.D.RHO(OHM-CM)	2.136	1.338	1.766	1.425	1.904	1.437	1.571
A.D.R-SQR(OHM)	46.906	48.946	49.399	50.305	43.054	47.359	52.798
AM0 VOC (MV)	.000	.000	.000	.000	.000	.000	.000
AM0 ISC (MA)	.000	.000	.000	.000	.000	.000	.000
AM0 VMP (MV)	.000	.000	.000	.000	.000	.000	.000
AM0 IMP (MA)	.000	.000	.000	.000	.000	.000	.000
AM0 FILL FCTR	.000	.000	.000	.000	.000	.000	.000
AM0 EFFICIENCY	.000	.000	.000	.000	.000	.000	.000
AM1 VOC (MV)	.000	.000	.000	.000	.000	.000	.000
AM1 ISC (MA)	.000	.000	.000	.000	.000	.000	.000
AM1 VMP (MV)	.000	.000	.000	.000	.000	.000	.000
AM1 IMP (MA)	.000	.000	.000	.000	.000	.000	.000
AM1 FILL FCTR	.000	.000	.000	.000	.000	.000	.000
AM1 EFFICIENCY	.000	.000	.000	.000	.000	.000	.000
AM1 EFF/AM0 EFF	.000	.000	.000	.000	.000	.000	.000
WHEN BROKEN	DICING	BACK ETCH	PRINTING	SPINNER	PRINTING	PRINTING	HCL BOIL

CELL NAME	A8	A9	B1	B2	B3	B4	B5
AREA (CM2)	6.450	6.450	6.450	6.450	6.450	6.450	6.450
THICK (CM)	.026	.034	.036	.036	.037	.036	.033
B.D.RHO(OHM-CM)	.000	2.642	1.338	1.644	1.579	1.330	1.661
A.D.R-SQR(OHM)	.000	55.517	46.000	48.946	48.719	49.172	48.946
AM0 VOC (MV)	.000	.000	.000	.000	.000	.000	.000
AM0 ISC (MA)	.000	.000	.000	.000	.000	.000	.000
AM0 VMP (MV)	.000	.000	.000	.000	.000	.000	.000
AM0 IMP (MA)	.000	.000	.000	.000	.000	.000	.000
AM0 FILL FCTR	.000	.000	.000	.000	.000	.000	.000
AM0 EFFICIENCY	.000	.000	.000	.000	.000	.000	.000
AM1 VOC (MV)	.000	.000	.000	.000	.000	.000	.000
AM1 ISC (MA)	.000	.000	.000	.000	.000	.000	.000
AM1 VMP (MV)	.000	.000	.000	.000	.000	.000	.000
AM1 IMP (MA)	.000	.000	.000	.000	.000	.000	.000
AM1 FILL FCTR	.000	.000	.000	.000	.000	.000	.000
AM1 EFFICIENCY	.000	.000	.000	.000	.000	.000	.000
AM1 EFF/AM0 EFF	.000	.000	.000	.000	.000	.000	.000
WHEN BROKEN	DICING	BACK ETCH	BACK ETCH	DICING	FIRING	DICING	V/I PROBE

CELL NAME	B6	B7	B8	B9	C1	C2	C3
AREA (CM2)	6.450	6.450	6.450	6.450	6.450	6.450	6.450
THICK (CM)	.030	.025	.029	.030	.033	.032	.034
B.D.RHO(OHM-CM)	1.265	1.197	.000	1.395	1.464	1.763	1.562
A.D.R-SQR(OHM)	51.891	53.024	.000	51.891	48.266	49.172	48.039
AM0 VOC (MV)	473.000	.000	.000	.000	.000	.000	.000
AM0 ISC (MA)	139.000	.000	.000	.000	.000	.000	.000
AM0 VMP (MV)	354.000	.000	.000	.000	.000	.000	.000
AM0 IMP (MA)	72.000	.000	.000	.000	.000	.000	.000
AM0 FILL FCTR	.388	.000	.000	.000	.000	.000	.000
AM0 EFFICIENCY	.029	.000	.000	.000	.000	.000	.000
AM1 VOC (MV)	.000	.000	.000	.000	.000	.000	.000
AM1 ISC (MA)	.000	.000	.000	.000	.000	.000	.000
AM1 VMP (MV)	.000	.000	.000	.000	.000	.000	.000
AM1 IMP (MA)	.000	.000	.000	.000	.000	.000	.000
AM1 FILL FCTR	.000	.000	.000	.000	.000	.000	.000
AM1 EFFICIENCY	.000	.000	.000	.000	.000	.000	.000
AM1 EFF/AM0 EFF	.000	.000	.000	.000	.000	.000	.000
WHEN BROKEN	SIMULATOR	HCL BOIL	HCL BOIL	DICING	BACK ETCH	PRINTING	DICING

Table 7 continued

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

EFG02

CELL NAME	C4	C5	C6	C7	C8	C9	D02
AREA (CM2)	6.450	6.450	6.450	6.450	6.450	6.450	6.45)
THICK (CM)	.037	.032	.029	.025	.028	.033	.032
B.D.RHO(OHM-CM)	1.360	1.343	1.357	1.635	1.488	1.399	.705
A.D.R-SOR(OHM)	42.719	47.359	52.116	52.116	52.345	.000	49.652
AM0 VOC (MV)	.000	.000	.000	.000	353.000	.000	478.000
AM0 ISC (MA)	.000	.000	.000	.000	140.000	.000	136.000
AM0 VMP (MV)	.000	.000	.000	.000	195.000	.000	368.000
AM0 IMP (MA)	.000	.000	.000	.000	75.000	.000	96.000
AM0 FILL FCTR	.000	.000	.000	.000	.296	.000	.543
AM0 EFFICIENCY	.000	.000	.000	.000	.017	.000	.040
AM1 VOC (MV)	.000	.000	.000	.000	.000	.000	.000
AM1 ISC (MA)	.000	.000	.000	.000	.000	.000	.000
AM1 VMP (MV)	.000	.009	.000	.000	.000	.000	.000
AM1 IMP (MA)	.000	.000	.000	.000	.000	.000	.000
AM1 FILL FCTR	.000	.000	.000	.000	.000	.000	.000
AM1 EFFICIENCY	.000	.000	.000	.000	.000	.000	.000
AM1 EFF/AM0 EFF	.000	.000	.000	.000	.000	.000	.000
WHEN BROKEN	SPINNER	FIRING AL	SPINNER	PRINTING		SPINNER	

CELL NAME	D1	D2	D3	D4	D5	D6	D7
AREA (CM2)	6.450	6.450	6.450	6.450	6.450	6.450	6.450
THICK (CM)	.034	.032	.034	.033	.032	.030	.025
B.D.RHO(OHM-CM)	1.275	.705	1.606	1.279	1.907	1.865	.000
A.D.R-SOR(OHM)	50.532	49.652	48.946	49.652	.000	.000	.000
AM0 VOC (MV)	.000	478.000	.000	.000	.000	.000	.000
AM0 ISC (MA)	.000	136.000	.000	.000	.000	.000	.000
AM0 VMP (MV)	.000	368.000	.000	.000	.000	.000	.000
AM0 IMP (MA)	.000	96.000	.000	.000	.000	.000	.000
AM0 FILL FCTR	.000	.543	.000	.000	.000	.000	.000
AM0 EFFICIENCY	.000	.040	.000	.000	.000	.000	.000
AM1 VOC (MV)	.000	.000	.000	.000	.000	.000	.000
AM1 ISC (MA)	.000	.000	.000	.000	.000	.000	.000
AM1 VMP (MV)	.000	.000	.000	.000	.000	.000	.000
AM1 IMP (MA)	.000	.000	.000	.000	.000	.003	.000
AM1 FILL FCTR	.000	.000	.000	.000	.000	.000	.000
AM1 EFFICIENCY	.000	.000	.000	.000	.000	.000	.000
AM1 EFF/AM0 EFF	.000	.000	.000	.000	.000	.000	.000
WHEN BROKEN	BACK ETCH		FIRING AL	PRINTING	V/I PROBE	V/I PROBE	DICING

CELL NAME	D8	D9	X1	X10	X7	X4	X5
AREA (CM2)	6.450	6.450	6.450	6.450	6.450	6.450	6.450
THICK (CM)	.028	.033	.022	.024	.024	.024	.024
B.D.RHO(OHM-CM)	.000	1.511	.000	.000	.000	.000	.000
A.D.R-SOR(OHM)	.000	51.891	94.266	58.463	52.118	52.571	53.024
AM0 VOC (MV)	.000	.000	586.000	582.000	585.000	.000	579.000
AM0 ISC (MA)	.000	.000	233.000	219.000	222.000	.000	218.000
AM0 VMP (MV)	.000	.000	462.000	469.000	470.000	.000	459.000
AM0 IMP (MA)	.000	.000	205.000	192.000	191.000	.000	194.000
AM0 FILL FCTR	.000	.000	.694	.706	.691	.000	.705
AM0 EFFICIENCY	.000	.000	.109	.103	.102	.000	.102
AM1 VOC (MV)	.000	.000	.000	.000	.000	.000	.000
AM1 ISC (MA)	.000	.000	.000	.000	.000	.000	.000
AM1 VMP (MV)	.000	.000	.000	.000	.000	.000	.000
AM1 IMP (MA)	.000	.000	.000	.000	.000	.000	.000
AM1 FILL FCTR	.000	.000	.000	.000	.000	.000	.000
AM1 EFFICIENCY	.000	.000	.000	.000	.000	.000	.000
AM1 EFF/AM0 EFF	.000	.000	.000	.000	.000	.000	.000
WHEN BROKEN	DICING	DICING				BACK ETCH	

Table 7 continued

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

EFG02

CELL NAME	X6	X7	X8	X9
AREA (CM2)	6.450	6.450	6.450	6.450
THICK (CM)	.023	.022	.022	.022
B.D.RHO(OHM-CM)	.000	.000	.000	13.307
A.D.R-SQR(OHM)	53.024	46.906	57.556	56.010
AM0 VOC (MV)	587.000	567.000	589.000	.000
AM0 ISC (MA)	228.000	230.000	222.000	.000
AM0 VMP (MV)	474.000	470.000	473.000	.000
AM0 IMP (MA)	197.000	202.000	197.000	.000
AM0 FILL FCTR	.698	.703	.713	.000
AM0 EFFICIENCY	.107	.109	.107	.000
AM1 VOC (MV)	.000	.000	.000	.000
AM1 ISC (MA)	.000	.000	.000	.000
AM1 VMP (MV)	.000	.000	.000	.000
AM1 IMP (MA)	.000	.000	.000	.000
AM1 FILL FCTR	.000	.000	.000	.000
AM1 EFFICIENCY	.000	.000	.000	.000
AM1 EFF/AM0 EFF	.000	.000	.000	.000

WHEN BROKEN SIMULATOR BACK ETCH

Table 8

SPECTRAL SENSITIVITY

EFG02

CELL NAME	C4	C5	C6	C7	C8	C9	D02
W.L. (MICRON)							
.41	.000	.000	.000	.000	.211	.000	.127
.45	.000	.000	.000	.000	.320	.000	.264
.50	.000	.000	.000	.000	.328	.000	.307
.55	.000	.000	.000	.000	.325	.000	.304
.60	.000	.000	.000	.000	.303	.000	.263
.65	.000	.000	.000	.000	.293	.000	.262
.70	.000	.000	.000	.000	.331	.000	.245
.75	.000	.000	.000	.000	.302	.000	.220
.80	.000	.000	.000	.000	.263	.000	.204
.85	.000	.000	.000	.000	.220	.000	.166
.90	.000	.000	.000	.000	.293	.000	.142
.95	.000	.000	.000	.000	.154	.000	.090
1.05	.000	.000	.000	.000	.096	.000	.031

CELL NAME	D1	D2	D3	D4	D5	D6	D7
W.L. (MICRON)							
.41	.000	.127	.000	.000	.000	.000	.000
.45	.000	.264	.000	.000	.000	.000	.000
.50	.000	.307	.000	.000	.000	.000	.000
.55	.000	.304	.000	.000	.000	.000	.000
.60	.000	.268	.000	.000	.000	.000	.000
.65	.000	.262	.000	.000	.000	.000	.000
.70	.000	.245	.000	.000	.000	.000	.000
.75	.000	.220	.000	.000	.000	.000	.000
.80	.000	.204	.000	.000	.000	.000	.000
.85	.000	.166	.000	.000	.000	.000	.000
.90	.000	.142	.000	.000	.000	.000	.000
.95	.000	.090	.000	.000	.000	.000	.000
1.05	.000	.031	.000	.000	.000	.000	.000

Table 8 continued

SPECTRAL SENSITIVITY

EFG02

CELL NAME	D6	D9	X1	X10	X3	X4	X5
W.L. (MICRON)							
.41	.000	.000	.025	.129	.130	.000	.122
.45	.000	.005	.129	.254	.262	.000	.261
.50	.000	.000	.172	.348	.343	.000	.345
.55	.000	.000	.194	.409	.400	.000	.413
.60	.000	.000	.207	.410	.423	.000	.423
.65	.000	.000	.223	.453	.454	.000	.467
.70	.000	.000	.240	.494	.487	.000	.500
.75	.000	.000	.257	.530	.530	.000	.543
.80	.000	.000	.276	.564	.573	.000	.592
.85	.000	.000	.291	.627	.597	.000	.618
.90	.000	.000	.313	.679	.658	.000	.673
.95	.000	.000	.328	.716	.707	.000	.713
1.05	.000	.000	.166	.353	.361	.000	.347

CELL NAME	X6	X7	X8	X9
W.L. (MICRON)				
.41	.145	.101	.119	.000
.45	.277	.151	.247	.000
.50	.355	.224	.343	.000
.55	.420	.257	.410	.000
.60	.440	.276	.425	.000
.65	.471	.282	.461	.000
.70	.506	.317	.495	.000
.75	.547	.340	.532	.000
.80	.600	.346	.595	.000
.85	.629	.382	.615	.000
.90	.663	.464	.644	.000
.95	.739	.445	.696	.000
1.05	[illegible]	.232	.376	.000

Table 9

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

HEM02

CELL NAME	1	10	11	12	13	14	15
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.045	.045	.045	.045	.045	.046	.046
B.D.RHO(OHM-CM)	.000	.062	.062	.061	.062	.083	.062
A.D.R-SQR(OHM)	.000	61.635	58.916	54.384	58.916	54.384	58.916
AM0 VOC (MV)	.000	587.000	567.000	567.000	585.000	597.000	594.000
AM0 ISC (MA)	.000	131.000	122.000	125.000	130.000	135.000	131.000
AM0 VMP (MV)	.000	472.000	482.000	493.000	480.000	495.000	483.000
AM0 IMP (MA)	.000	119.000	106.000	118.000	120.000	125.000	118.000
AM0 FILL FCTR	.000	.730	.713	.793	.757	.768	.732
AM0 EFFICIENCY	.000	.104	.094	.107	.106	.114	.105
AM1 VOC (MV)	.000	588.000	.000	588.000	582.000	598.000	593.000
AM1 ISC (MA)	.000	116.000	.000	107.000	109.000	116.000	110.000
AM1 VMP (MV)	.000	476.000	.000	497.000	486.000	498.000	491.000
AM1 IMP (MA)	.000	100.000	.000	101.000	102.000	109.000	101.000
AM1 FILL FCTR	.000	.701	.000	.796	.781	.783	.760
AM1 EFFICIENCY	.000	.119	.000	.125	.124	.136	.124
AM1 EFF/AM0 EFF	.000	1.151	.000	1.167	1.164	1.187	1.177

WHEN BROKEN	BACK ETCH	0	0	0	0	0	0

Table 9 continued

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

HEM02

CELL NAME	2	3	4	5	6	7	8
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.046	.045	.045	.046	.045	.045	.046
B.D.RHO(OHM-CM)	.083	.082	.061	.062	.061	.062	.083
A.D.R-SQR(OHM)	59.369	61.635	60.729	58.916	59.822	58.463	58.010
AM0 VOC (MV)	593.000	.000	565.000	.000	.000	589.000	582.000
AM0 ISC (MA)	140.000	.000	131.000	.000	.000	132.000	132.000
AM0 VMP (MV)	475.000	.000	471.000	.000	.000	486.000	477.000
AM0 IMP (MA)	116.000	.000	106.000	.000	.000	119.000	98.000
AM0 FILL FCTR	.664	.000	.651	.000	.000	.744	.608
AM0 EFFICIENCY	.102	.000	.092	.000	.000	.107	.086
AM1 VOC (MV)	.000	.000	.000	.000	.000	589.000	.000
AM1 ISC (MA)	.000	.000	.000	.000	.000	113.000	.000
AM1 VMP (MV)	.000	.000	.000	.000	.000	491.000	.000
AM1 IMP (MA)	.000	.000	.000	.000	.000	100.000	.000
AM1 FILL FCTR	.000	.000	.000	.000	.000	.738	.000
AM1 EFFICIENCY	.000	.000	.000	.000	.000	.123	.000
AM1 EFF/AM0 EFF	.000	.000	.000	.000	.000	1.149	.000
WHEN BROKEN	UNLOADING?	EDGE ETCH?	EDGE ETCH?	NO RECORD?	0	0	0

CELL NAME	9	X1	X2	X3	X4	X5	X6
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.046	.023	.023	.023	.023	.023	.023
B.D.RHO(OHM-CM)	.083	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	58.916	61.182	57.103	53.931	59.369	54.837	50.758
AM0 VOC (MV)	585.000	583.000	598.000	566.000	604.000	.000	604.000
AM0 ISC (MA)	130.000	144.000	153.000	143.000	150.000	.000	153.000
AM0 VMP (MV)	460.000	476.000	482.000	441.000	487.000	.000	491.000
AM0 IMP (MA)	120.000	133.000	134.000	118.000	129.000	.000	134.000
AM0 FILL FCTR	.757	.754	.706	.643	.693	.000	.712
AM0 EFFICIENCY	.106	.117	.119	.096	.116	.000	.122
AM1 VOC (MV)	.000	586.000	.000	.000	.000	.000	.000
AM1 ISC (MA)	.000	124.000	.000	.000	.000	.000	.000
AM1 VMP (MV)	.000	489.000	.000	.000	.000	.000	.000
AM1 IMP (MA)	.000	116.000	.000	.000	.000	.000	.000
AM1 FILL FCTR	.000	.781	.000	.000	.000	.000	.000
AM1 EFFICIENCY	.000	.142	.000	.000	.000	.000	.000
AM1 EFF/AM0 EFF	.000	1.212	.000	.000	.000	.000	.000
WHEN BROKEN	0	0	0	0	0	NOT STABLE	0

CELL NAME	X7	X8
AREA (CM2)	4.000	4.000
THICK (CM)	.023	.023
B.D.RHO(OHM-CM)	.000	.000
A.D.R-SQR(OHM)	48.946	49.852
AM0 VOC (MV)	595.000	595.000
AM0 ISC (MA)	146.000	150.000
AM0 VMP (MV)	482.000	484.000
AM0 IMP (MA)	136.000	109.000
AM0 FILL FCTR	.779	.591
AM0 EFFICIENCY	.123	.097
AM1 VOC (MV)	565.000	.000
AM1 ISC (MA)	123.000	.000
AM1 VMP (MV)	489.000	.000
AM1 IMP (MA)	116.000	.000
AM1 FILL FCTR	.788	.000
AM1 EFFICIENCY	.142	.000
AM1 EFF/AM0 EFF	1.154	.000
WHEN BROKEN	0	0

Table 10

SPECTRAL SENSITIVITY

HEMO2

CELL NAME W.L. (MICRON)	1	10	11	12	13	14	15
.41	.178	.116	.101	.099	.101	.105	.104
.45	.319	.277	.256	.251	.257	.261	.261
.50	.395	.384	.355	.367	.371	.379	.372
.55	.451	.434	.391	.420	.425	.431	.416
.60	.460	.448	.409	.454	.456	.467	.447
.65	.495	.478	.414	.471	.469	.450	.452
.70	.547	.495	.406	.466	.479	.505	.450
.75	.575	.526	.413	.504	.492	.535	.460
.80	.581	.535	.381	.523	.497	.575	.468
.85	.582	.488	.351	.490	.465	.552	.439
.90	.612	.463	.273	.428	.398	.506	.382
.95	.519	.396	.205	.343	.309	.454	.316
1.05	.218	.147	.054	.095	.081	.139	.093

CELL NAME W.L. (MICRON)	2	3	4	5	6	7	8
.41	.129	.166	.128	.169	.139	.134	.168
.45	.284	.315	.293	.314	.289	.290	.321
.50	.394	.390	.393	.383	.383	.388	.397
.55	.447	.424	.434	.424	.426	.433	.443
.60	.500	.450	.464	.453	.457	.466	.478
.65	.521	.451	.469	.461	.462	.473	.486
.70	.537	.480	.483	.496	.485	.491	.526
.75	.571	.485	.495	.502	.493	.514	.547
.80	.594	.486	.497	.512	.506	.538	.564
.85	.000	.460	.458	.480	.485	.514	.544
.90	.578	.460	.424	.499	.466	.467	.552
.95	.541	.361	.330	.408	.392	.416	.459
1.05	.209	.147	.109	.169	.141	.141	.179

CELL NAME W.L. (MICRON)	9	X1	X2	X3	X4	X5	X6
.41	.119	.116	.120	.115	.146	.000	.138
.45	.275	.274	.278	.273	.289	.000	.263
.50	.396	.396	.394	.390	.395	.000	.392
.55	.440	.456	.448	.453	.459	.000	.461
.60	.479	.494	.477	.486	.501	.000	.503
.65	.497	.512	.514	.513	.522	.000	.529
.70	.522	.545	.543	.548	.566	.000	.564
.75	.556	.591	.587	.594	.620	.000	.621
.80	.591	.625	.611	.622	.656	.000	.652
.85	.602	.647	.640	.643	.665	.000	.701
.90	.605	.678	.677	.681	.772	.000	.792
.95	.587	.642	.687	.624	.811	.000	.816
1.05	.243	.258	.293	.232	.405	.000	.410

CELL NAME W.L. (MICRON)	X7	X8
.41	.120	.176
.45	.279	.314
.50	.398	.400
.55	.453	.467
.60	.496	.467
.65	.517	.525
.70	.550	.594
.75	.554	.678
.80	.632	.681
.85	.649	.699
.90	.679	.813
.95	.646	.824
1.05	.259	.405

Table 11

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

[illegible]EM03-1

CELL NAME	A1	A2	A3	A4	B1	B2	B3
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.044	.044	.045	.044	.044	.046	.044
B.D.RHO(OHM-CM)	.060	.060	.061	.081	.081	.083	.081
A.D.R-SQR(OHM)	42.601	42.601	39.428	40.335	42.148	43.507	41.694
AM0 VOC (MV)	581.000	598.000	606.000	.000	580.000	462.000	598.000
AM0 ISC (MA)	118.000	128.000	137.000	.000	123.000	130.000	134.000
AM0 VMP (MV)	466.000	561.000	507.000	.000	484.000	248.000	478.000
AM0 IMP (MA)	96.000	121.000	129.000	.000	117.000	108.000	125.000
AM0 FILL FCTR	.653	.792	.788	.000	.794	.446	.746
AM0 EFFICIENCY	.083	.112	.121	.000	.105	.049	.110
AM1 VOC (MV)	.000	.000	605.000	.000	.000	.000	.000
AM1 ISC (MA)	.000	.000	121.000	.000	.000	.000	.000
AM1 VMP (MV)	.000	.000	509.000	.000	.000	.000	.000
AM1 IMP (MA)	.000	.000	113.000	.000	.000	.000	.000
AM1 FILL FCTR	.000	.000	.766	.000	.000	.000	.000
AM1 EFFICIENCY	.000	.000	.144	.000	.000	.000	.000
AM1 EFF/AM0 EFF	.000	.000	1.190	.000	.000	.000	.000
WHEN BROKEN	0	0	0	SCRIBING	0	0	0

CELL NAME	B4	C1	C2	C3	C4	D1	D2
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.046	.043	.043	.044	.044	.043	.043
B.D.RHO(OHM-CM)	.083	.039	.059	.040	.060	.059	.059
A.D.R-SQR(OHM)	43.054	39.428	39.428	40.709	41.694	41.241	45.320
AM0 VOC (MV)	593.000	595.000	286.000	600.000	593.000	.000	600.000
AM0 ISC (MA)	131.000	133.000	132.000	131.000	124.000	.000	133.000
AM0 VMP (MV)	492.000	484.000	180.000	500.000	491.000	.000	502.000
AM0 IMP (MA)	121.000	117.000	105.000	121.000	110.000	.000	125.000
AM0 FILL FCTR	.766	.716	.501	.770	.735	.000	.786
AM0 EFFICIENCY	.110	.105	.035	.112	.100	.000	.116
AM1 VOC (MV)	592.000	.000	.000	599.000	.000	.000	598.000
AM1 ISC (MA)	114.000	.000	.000	114.000	.000	.000	116.000
AM1 VMP (MV)	495.000	.000	.000	501.000	.000	.000	502.000
AM1 IMP (MA)	105.000	.000	.000	104.000	.000	.000	107.000
AM1 FILL FCTR	.774	.000	.000	.763	.000	.000	.774
AM1 EFFICIENCY	.130	.000	.000	.130	.000	.000	.134
AM1 EFF/AM0 EFF	1.181	.000	.000	1.165	.000	.000	1.150
WHEN BROKEN	0	0	0	0	0	BACK ETCH	0

CELL NAME	D3	D4	E1	E2	E3	E4	F1
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.046	.046	.043	.044	.044	.043	.043
B.D.RHO(OHM-CM)	.083	.062	.137	.141	.141	.117	.108
A.D.R-SQR(OHM)	41.694	46.226	51.665	49.399	50.758	48.039	48.039
AM0 VOC (MV)	588.000	578.000	453.000	569.000	493.000	522.000	.000
AM0 ISC (MA)	126.000	120.000	130.000	116.000	122.000	110.000	.000
AM0 VMP (MV)	484.000	476.000	272.000	473.000	310.000	387.000	.000
AM0 IMP (MA)	110.000	112.000	100.000	107.000	90.000	78.000	.000
AM0 FILL FCTR	.707	.769	.462	.754	.464	.526	.000
AM0 EFFICIENCY	.096	.099	.050	.094	.052	.056	.000
AM1 VOC (MV)	.000	.000	.000	567.000	.000	.000	.000
AM1 ISC (MA)	.000	.000	.000	104.000	.000	.000	.000
AM1 VMP (MV)	.000	.000	.000	463.000	.000	.000	.000
AM1 IMP (MA)	.000	.000	.000	94.000	.000	.000	.000
AM1 FILL FCTR	.000	.000	.000	.738	.000	.000	.000
AM1 EFFICIENCY	.000	.000	.000	.109	.000	.000	.000
AM1 EFF/AM0 EFF	.000	.000	.000	1.163	.000	.000	.000
WHEN BROKEN	DROPPED	0	0	0	0	DROPPED	SCRIBING

Table 11 continued

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

HEM03-1

CELL NAME	F2	F3	F4	X1	X2	X3	X4
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.043	.000	.000	.023	.023	.023	.023
B.D.RHO(OHM-CM)	.098	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	47.359	.000	.000	45.773	46.660	48.492	51.212
AM0 VOC (MV)	555.000	568.000	.000	577.000	581.000	593.000	581.000
AM0 ISC (MA)	114.000	124.000	.000	139.000	140.000	139.000	131.000
AM0 VMP (MV)	435.000	453.000	.000	466.000	482.000	476.000	483.000
AM0 IMP (MA)	85.000	98.000	.000	123.000	131.000	132.000	123.000
AM0 FILL FCTR	.584	.630	.000	.715	.776	.779	.781
AM0 EFFICIENCY	.068	.082	.000	.106	.117	.117	.110
AM1 VOC (MV)	.000	567.000	.000	.000	581.000	.000	.000
AM1 ISC (MA)	.000	109.000	.000	.000	121.000	.000	.000
AM1 VMP (MV)	.000	447.000	.000	.000	485.000	.000	.000
AM1 IMP (MA)	.000	85.000	.000	.000	111.000	.000	.000
AM1 FILL FCTR	.000	.615	.000	.000	.766	.000	.000
AM1 EFFICIENCY	.000	.095	.000	.000	.135	.000	.000
AM1 EFF/AM0 EFF	.000	1.158	.000	.000	1.154	.000	.000
WHEN BROKEN	0	0	SCRIBING	0	0	DROPPED	0

CELL NAME	X5	X6	X7	X8
AREA (CM2)	4.000	4.000	4.000	4.000
THICK (CM)	.027	.023	.023	.023
B.D.RHO(OHM-CM)	.000	.000	.000	.000
A.D.R-SQR(OHM)	43.960	62.542	42.601	49.852
AM0 VOC (MV)	563.000	582.000	584.000	537.000
AM0 ISC (MA)	139.000	140.000	136.000	177.000
AM0 VMP (MV)	472.000	493.000	485.000	366.000
AM0 IMP (MA)	132.000	132.000	131.000	71.000
AM0 FILL FCTR	.769	.782	.786	.357
AM0 EFFICIENCY	.115	.118	.117	.048
AM1 VOC (MV)	.000	582.000	584.000	.000
AM1 ISC (MA)	.000	122.000	119.000	.000
AM1 VMP (MV)	.000	465.000	469.000	.000
AM1 IMP (MA)	.000	113.000	112.000	.000
AM1 FILL FCTR	.000	.772	.768	.000
AM1 EFFICIENCY	.000	.137	.137	.000
AM1 EFF/AM0 EFF	.000	1.163	1.166	.000
WHEN BROKEN	0	0	0	0

Table 12

SPECTRAL SENSITIVITY

HEM03-1

CELL NAME	A1	A2	A3	A4	B1	B2	B3
W.L. (MICRON)							
.41	.106	.117	.135	.000	.134	.135	.135
.45	.260	.274	.304	.000	.306	.305	.309
.50	.364	.322	.415	.000	.407	.420	.413
.55	.410	.432	.462	.000	.437	.466	.458
.60	.440	.459	.495	.000	.471	.502	.496
.65	.457	.484	.514	.000	.471	.512	.511
.70	.456	.493	.524	.000	.459	.520	.520
.75	.479	.529	.567	.000	.466	.546	.554
.80	.509	.549	.599	.000	.473	.569	.618
.85	.483	.559	.571	.000	.429	.541	.594
.90	.434	.541	.588	.000	.355	.492	.570
.95	.381	.487	.552	.000	.272	.402	.513
1.05	.120	.165	.200	.000	.072	.125	.189

Table 12 continued

SPECTRAL SENSITIVITY

HEMO3-1

CELL NAME W.L. (MICRON)	B4	C1	C2	C3	C4	D1	D2
.41	.127	.142	.126	.121	.138	.000	.140
.45	.306	.318	.297	.266	.313	.000	.312
.50	.415	.417	.398	.385	.406	.000	.420
.55	.462	.456	.436	.423	.438	.000	.467
.60	.494	.483	.467	.450	.462	.000	.500
.65	.508	.498	.476	.467	.470	.000	.517
.70	.515	.493	.465	.459	.452	.000	.531
.75	.541	.519	.463	.483	.461	.000	.563
.80	.563	.567	.522	.515	.491	.000	.600
.85	.548	.538	.506	.497	.463	.000	.587
.90	.508	.472	.434	.439	.379	.000	.550
.95	.418	.424	.396	.391	.323	.000	.461
1.05	.125	.131	.127	.121	.092	.000	.163

CELL NAME W.L. (MICRON)	D3	D4	E1	E2	E3	E4	F1
.41	.000	.133	.113	.111	.102	.000	.000
.45	.000	.306	.260	.276	.268	.000	.000
.50	.000	.404	.408	.385	.388	.000	.000
.55	.000	.459	.454	.423	.434	.000	.000
.60	.000	.451	.488	.447	.465	.000	.000
.65	.000	.444	.499	.247	.470	.000	.000
.70	.000	.426	.489	.441	.465	.000	.000
.75	.000	.427	.505	.452	.470	.000	.000
.80	.000	.423	.523	.447	.480	.000	.000
.85	.000	.374	.480	.406	.433	.000	.000
.90	.000	.303	.395	.327	.351	.000	.000
.95	.000	.236	.309	.241	.269	.000	.000
1.05	.000	.061	.084	.062	.073	.000	.000

CELL NAME W.L. (MICRON)	F2	F3	F4	X1	X2	X3	X4
.41	.099	.107	.000	.129	.134	.000	.123
.45	.249	.266	.000	.291	.297	.000	.285
.50	.362	.366	.000	.416	.421	.000	.393
.55	.415	.445	.000	.476	.477	.000	.444
.60	.453	.490	.000	.515	.518	.000	.478
.65	.472	.506	.000	.540	.543	.000	.500
.70	.484	.532	.000	.568	.569	.000	.511
.75	.518	.559	.000	.616	.616	.000	.559
.80	.539	.606	.000	.651	.663	.000	.586
.85	.525	.586	.000	.667	.676	.000	.596
.90	.499	.600	.000	.697	.697	.000	.581
.95	.421	.490	.000	.649	.655	.000	.532
1.05	.143	.180	.000	.257	.266	.000	.181

CELL NAME W.L. (MICRON)	X5	X6	X7	X8
.41	.139	.135	.132	.253
.45	.309	.300	.300	.396
.50	.420	.417	.412	.448
.55	.473	.474	.467	.491
.60	.504	.511	.491	.516
.65	.530	.536	.524	.535
.70	.548	.560	.544	.612
.75	.590	.608	.595	.646
.80	.638	.651	.615	.665
.85	.640	.662	.639	.667
.90	.648	.689	.648	.764
.95	.592	.636	.611	.650
1.05	.229	.258	.232	.302

Table 13

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

HEMO4

CELL NAME	21	23	24	25	26	27	28
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.025	.025	.025	.025	.025	.025	.025
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	49.852	49.399	50.756	49.852	49.852	49.852	.000
AM0 VOC (MV)	601.000	601.000	596.000	14.000	.000	602.000	599.000
AM0 ISC (MA)	128.000	125.000	122.000	126.000	.000	128.000	128.000
AM0 VMP (MV)	509.000	516.000	.000	.000	.000	515.000	511.000
AM0 IMP (MA)	119.000	116.000	.000	.000	.000	116.400	115.000
AM0 FILL FCTR	.787	.797	.000	.000	.000	.778	.766
AM0 EFFICIENCY	.112	.111	.000	.000	.000	.111	.109
AM1 VOC (MV)	596.000	599.000	.000	.000	.000	599.000	597.000
AM1 ISC (MA)	110.000	107.000	.000	.000	.000	110.000	110.000
AM1 VMP (MV)	511.000	517.000	.000	.000	.000	515.000	511.000
AM1 IMP (MA)	102.000	98.000	.000	.000	.000	100.000	99.000
AM1 FILL FCTR	.792	.791	.000	.000	.000	.762	.770
AM1 EFFICIENCY	.130	.127	.000	.000	.000	.129	.126
AM1 EFF/AM0 EFF	1.164	1.145	.000	.000	.000	1.162	1.165
WHEN BROKEN			SHORTED	SHORTED	CHIPPED	CHIPPED	

CELL NAME	41	43	45	46	47	91	92
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.025	.025	.025	.025	.025	.025	.025
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	52.571	49.852	49.852	49.399	48.946	45.320	46.226
AM0 VOC (MV)	586.000	583.000	601.000	601.000	585.000	581.000	591.000
AM0 ISC (MA)	122.000	124.000	128.000	128.000	123.000	120.000	124.000
AM0 VMP (MV)	492.000	489.000	509.000	509.000	489.000	486.000	497.000
AM0 IMP (MA)	113.000	108.000	120.000	120.000	111.000	107.000	110.000
AM0 FILL FCTR	.778	.731	.794	.794	.754	.749	.746
AM0 EFFICIENCY	.103	.098	.113	.113	.100	.096	.101
AM1 VOC (MV)	583.000	581.000	599.000	44.000	582.000	578.000	586.000
AM1 ISC (MA)	106.000	107.000	110.000	107.000	108.000	104.000	107.000
AM1 VMP (MV)	497.000	487.000	509.000	.000	489.000	489.000	496.000
AM1 IMP (MA)	99.000	93.000	103.000	.000	96.000	92.000	96.000
AM1 FILL FCTR	.796	.729	.796	.000	.747	.748	.760
AM1 EFFICIENCY	.123	.113	.131	.000	.117	.112	.120
AM1 EFF/AM0 EFF	1.197	1.160	1.161	.000	1.170	1.166	1.183
WHEN BROKEN		CHIPPED		SHORTED			

CELL NAME	94	97	98	X10	X11	X12	X13
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.025	.025	.025	.025	.025	.025	.025
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	47.133	46.226	46.226	44.867	45.773	46.226	45.320
AM0 VOC (MV)	598.000	587.000	599.000	601.000	597.000	601.000	598.000
AM0 ISC (MA)	130.000	112.000	130.000	136.000	137.000	135.000	132.000
AM0 VMP (MV)	502.000	463.000	501.000	506.000	502.000	514.000	509.000
AM0 IMP (MA)	115.000	80.000	116.000	127.000	123.000	123.000	123.000
AM0 FILL FCTR	.743	.563	.746	.786	.755	.779	.793
AM0 EFFICIENCY	.107	.068	.107	.119	.114	.117	.116
AM1 VOC (MV)	596.000	45.000	597.000	599.000	594.000	598.000	596.000
AM1 ISC (MA)	111.000	81.000	112.000	117.000	118.000	116.000	114.000
AM1 VMP (MV)	497.000	.000	501.000	506.000	504.000	512.000	509.000
AM1 IMP (MA)	97.000	.000	99.000	109.000	106.000	106.000	105.000
AM1 FILL FCTR	.729	.000	.742	.767	.762	.762	.767
AM1 EFFICIENCY	.121	.000	.124	.136	.134	.136	.134
AM1 EFF/AM0 EFF	1.130	.000	1.155	1.161	1.171	1.161	1.155
WHEN BROKEN		SHORTED					

Table 13 continued

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

HEM04

CELL NAME	X14	X2	X3	X4	X5	X7	X9
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.025	.025	.025	.025	.025	.025	.025
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	46.226	51.665	48.946	48.039	49.399	50.758	45.320
AM0 VOC (MV)	597.000	564.000	581.000	601.000	599.000	600.000	603.000
AM0 ISC (MA)	134.000	137.000	135.000	136.000	136.000	134.000	136.000
AM0 VMP (MV)	509.000	495.000	487.000	510.000	513.000	511.000	513.000
AM0 IMP (MA)	124.000	128.000	123.000	126.000	125.000	126.000	127.000
AM0 FILL FCTR	.769	.792	.764	.786	.787	.801	.794
AM0 EFFICIENCY	.117	.117	.111	.119	.118	.119	.120
AM1 VOC (MV)	595.000	582.000	578.000	599.000	596.000	597.000	601.000
AM1 ISC (MA)	115.000	118.000	116.000	116.000	116.000	115.000	116.000
AM1 VMP (MV)	507.000	493.000	4[illegible]7.000	512.000	512.000	512.000	512.000
AM1 IMP (MA)	106.000	111.000	1[illegible]6.000	108.000	107.000	107.000	109.000
AM1 FILL FCTR	.785	.797	.770	.796	.792	.798	.801
AM1 EFFICIENCY	.134	.137	.129	.138	.137	.137	.140
AM1 EFF/AM0 EFF	1.152	1.169	1.166	1.164	1.156	1.151	1.159

WHEN BROKEN

Table 14

SPECTRAL SENSITIVITY

HEM04

CELL NAME	21	23	24	25	26	27	28
W.L. (MICRON)							
.41	.110	.113	.104	.108	.131	.106	.105
.45	.259	.262	.260	.257	.271	.265	.252
.50	.375	.374	.372	.366	.350	.370	.359
.55	.430	.411	.424	.403	.375	.428	.409
.60	.449	.450	.444	.431	.369	.450	.448
.65	.477	.475	.472	.453	.375	.473	.470
.70	.487	.478	.472	.459	.368	.485	.478
.75	.541	.524	.506	.498	.356	.527	.514
.80	.553	.548	.502	.507	.317	.542	.537
.85	.553	.534	.493	.487	.252	.553	.540
.90	.507	.504	.435	.416	.221	.516	.485
.95	.455	.453	.345	.353	.123	.463	.446
1.05	.147	.151	.093	.097	.047	.141	.156

Table 14 continued

SPECTRAL SENSITIVITY

HEM04

CELL NAME	41	43	45	46	47	91	92
W.L. (MICRON)							
.41	.086	.092	.098	.085	.097	.081	.096
.45	.227	.210	.255	.231	.245	.218	.240
.50	.341	.344	.354	.344	.362	.335	.358
.55	.394	.400	.405	.385	.409	.391	.400
.60	.425	.436	.441	.422	.440	.430	.436
.65	.447	.455	.459	.442	.458	.466	.457
.70	.470	.474	.480	.465	.481	.474	.445
.75	.505	.512	.510	.500	.521	.522	.484
.80	.535	.546	.545	.527	.536	.544	.496
.85	.522	.540	.544	.532	.539	.538	.467
.90	.466	.513	.504	.491	.506	.498	.377
.95	.432	.453	.459	.436	.454	.454	.324
1.05	.141	.150	.148	.146	.152	.148	.092

CELL NAME	94	97	98	X10	X11	X12	X13
W.L. (MICRON)							
.41	.103	.107	.096	.110	.120	.112	.110
.45	.245	.244	.244	.278	.288	.281	.259
.50	.352	.336	.356	.415	.404	.391	.379
.55	.394	.373	.402	.466	.456	.446	.425
.60	.434	.416	.432	.496	.499	.474	.459
.65	.450	.421	.453	.523	.517	.500	.494
.70	.456	.413	.452	.539	.550	.516	.507
.75	.475	.433	.477	.585	.587	.558	.561
.80	.509	.444	.513	.595	.627	.608	.592
.85	.496	.412	.506	.601	.629	.614	.597
.90	.406	.326	.419	.545	.623	.598	.586
.95	.389	.264	.394	.507	.598	.566	.578
1.05	.116	.077	.114	.164	.237	.226	.222

CELL NAME	X14	X2	X3	X4	X5	X7	X9
W.L. (MICRON)							
.41	.104	.122	.117	.121	.122	.121	.09[illegible]
.45	.275	.287	.276	.264	.261	.279	.251
.50	.366	.411	.402	.399	.369	.410	.372
.55	.426	.462	.461	.445	.467	.453	.438
.60	.468	.494	.465	.478	.492	.474	.470
.65	.472	.519	.522	.504	.527	.498	.522
.70	.501	.525	.546	.516	.536	.518	.522
.75	.559	.586	.602	.574	.580	.574	.554
.80	.594	.634	.640	.626	.621	.605	.582
.85	.596	.635	.635	.629	.628	.622	.559
.90	.580	.624	.627	.635	.616	.604	.494
.95	.543	.604	.593	.611	.571	.574	.451
1.05	.196	.241	.228	.239	.211	.220	.137

Table 15

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

AAMCB-1

CELL NAME	A1	A10	A11	A12	A13	A2	A3
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.061	.061	.061	.061	.061	.061	.061
B.D.RHO(OHM-CM)	3.329	3.329	3.329	3.329	3.329	3.329	3.329
A.D.R-SQR(OHM)	45.320	51.665	48.946	46.680	47.133	45.773	46.226
AM0 VOC (MV)	581.000	581.000	575.000	577.000	.000	578.000	582.000
AM0 ISC (MA)	138.000	139.000	136.000	140.000	.000	138.000	141.000
AM0 VMP (MV)	491.000	460.000	476.000	476.000	.000	482.000	480.000
AM0 IMP (MA)	130.000	130.000	116.000	126.000	.000	131.000	135.000
AM0 FILL FCTR	.796	.740	.706	.742	.000	.792	.790
AM0 EFFICIENCY	.116	.110	.102	.111	.000	.117	.120
AM1 VOC (MV)	580.000	.000	.000	.000	.000	580.000	582.000
AM1 ISC (MA)	124.000	.000	.000	.000	.000	125.000	127.000
AM1 VMP (MV)	491.000	.000	.000	.000	.000	484.000	484.000
AM1 IMP (MA)	116.000	.000	.000	.000	.000	116.000	120.000
AM1 FILL FCTR	.792	.000	.000	.000	.000	.768	.766
AM1 EFFICIENCY	.142	.000	.000	.000	.000	.143	.145
AM1 EFF/AM0 EFF	1.207	.000	.000	.000	.000	1.224	1.213
WHEN BROKEN	0	0	0	0	SPEC.RESP.	0	0

CELL NAME	A4	A5	A6	A7	A8	A9	B1
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.061	.061	.061	.061	.061	.061	.061
B.D.RHO(OHM-CM)	3.329	3.329	3.329	3.329	3.329	3.329	3.343
A.D.R-SQR(OHM)	46.226	48.492	49.399	49.652	50.758	49.399	45.773
AM0 VOC (MV)	.000	578.000	579.000	569.000	556.000	572.000	566.000
AM0 ISC (MA)	.000	140.000	137.000	135.000	138.000	139.000	133.000
AM0 VMP (MV)	.000	412.000	477.000	460.000	435.000	467.000	460.000
AM0 IMP (MA)	.000	122.000	129.000	108.000	100.000	116.000	106.000
AM0 FILL FCTR	.000	.621	.776	.647	.567	.681	.648
AM0 EFFICIENCY	.000	.093	.114	.092	.080	.100	.090
AM1 VOC (MV)	.000	.000	579.000	.000	.000	.000	.000
AM1 ISC (MA)	.000	.000	123.000	.000	.000	.000	.000
AM1 VMP (MV)	.000	.000	479.000	.000	.000	.000	.000
AM1 IMP (MA)	.000	.000	115.000	.000	.000	.000	.000
AM1 FILL FCTR	.000	.000	.773	.000	.000	.000	.000
AM1 EFFICIENCY	.000	.000	.138	.000	.000	.000	.000
AM1 EFF/AM0 EFF	.000	.000	1.211	.000	.000	.000	.000
WHEN BROKEN	EDGE ETCH	0	0	0	0	0	0

CELL NAME	B10	B11	B12	B13	B2	B3	B4
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.061	.061	.061	.061	.061	.061	.061
B.D.RHO(OHM-CM)	3.315	3.343	3.343	3.329	3.343	3.343	3.343
A.D.R-SQR(OHM)	50.758	47.133	47.133	47.586	46.226	47.586	49.852
AM0 VOC (MV)	551.000	424.000	581.000	.000	574.000	575.000	581.000
AM0 ISC (MA)	137.000	134.000	137.000	.000	140.000	138.000	138.000
AM0 VMP (MV)	397.000	244.000	466.000	.000	413.000	477.000	476.000
AM0 IMP (MA)	96.000	95.000	129.000	.000	105.000	126.000	130.000
AM0 FILL FCTR	.505	.408	.788	.000	.540	.757	.775
AM0 EFFICIENCY	.070	.043	.116	.000	.080	.111	.115
AM1 VOC (MV)	.000	.000	581.000	.000	.000	.000	580.000
AM1 ISC (MA)	.000	.000	124.000	.000	.000	.000	124.000
AM1 VMP (MV)	.000	.000	482.000	.000	.000	.000	479.000
AM1 IMP (MA)	.000	.000	116.000	.000	.000	.000	116.000
AM1 FILL FCTR	.000	.000	.776	.000	.000	.000	.773
AM1 EFFICIENCY	.000	.000	.140	.000	.000	.000	.139
AM1 EFF/AM0 EFF	.000	.000	1.207	.000	.000	.000	1.210
WHEN BROKEN	0	0	0	EDGE ETCH	0		0

Table 15 continued

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

HAMCO-1

CELL NAME	B5	B6	B7	B8	B9	X1	X2
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.061	.061	.061	.061	.061	.023	.023
B.D.RHO(OHM-CM)	3.343	3.343	3.329	3.329	3.329	.000	.000
A.D.R-SQR(OHM)	48.492	48.946	46.226	50.758	53.024	45.320	46.226
AM0 VOC (MV)	577.000	571.000	462.000	579.000	578.000	598.000	596.000
AM0 ISC (MA)	135.000	139.000	133.000	139.000	138.000	135.000	136.000
AM0 VMP (MV)	482.000	473.000	268.000	480.000	481.000	507.000	502.000
AM0 IMP (MA)	126.000	118.000	95.000	130.000	131.000	129.000	116.000
AM0 FILL FCTR	.780	.703	.414	.775	.790	.810	.718
AM0 EFFICIENCY	.112	.103	.047	.115	.116	.121	.108
AM1 VOC (MV)	576.000	.000	.000	578.000	578.000	595.000	.000
AM1 ISC (MA)	121.000	.000	.000	125.000	124.000	120.000	.000
AM1 VMP (MV)	430.000	.000	.000	479.000	486.000	502.000	.000
AM1 IMP (MA)	113.000	.000	.000	116.000	115.000	114.000	.000
AM1 FILL FCTR	.778	.000	.000	.769	.783	.802	.000
AM1 EFFICIENCY	.136	.000	.000	.139	.140	.143	.000
AM1 EFF/AM0 EFF	1.208	.000	.000	1.205	1.205	1.164	.000
WHEN BROKEN	0	0		0	0	0	0

CELL NAME	X3	X4	X5	X6	X7	X8
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.023	.023	.023	.023	.023	.023
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	49.852	50.758	48.492	47.586	47.586	50.758
AM0 VOC (MV)	594.000	598.000	583.000	556.000	583.000	.000
AM0 ISC (MA)	135.000	135.000	145.000	134.000	145.000	.000
AM0 VMP (MV)	501.000	504.000	484.000	504.000	482.000	.000
AM0 IMP (MA)	127.000	125.000	137.000	127.000	137.000	.000
AM0 FILL FCTR	.793	.780	.784	.801	.781	.000
AM0 EFFICIENCY	.118	.116	.123	.118	.122	.000
AM1 VOC (MV)	.000	.000	.000	.000	581.000	.000
AM1 ISC (MA)	.000	.000	.000	.000	128.000	.000
AM1 VMP (MV)	.000	.000	.000	.000	485.000	.000
AM1 IMP (MA)	.000	.000	.000	.000	120.000	.000
AM1 FILL FCTR	.000	.000	.000	.000	.763	.000
AM1 EFFICIENCY	.000	.000	.000	.000	.146	.000
AM1 EFF/AM0 EFF	.000	.000	.000	.000	1.192	.000
WHEN BROKEN	0	0	0	0	0	LOST

Table 16

DARK CURRENT DENSITY, RUN HamcB-1

V_F/S/N	C1	C2	C3	C4	C5	C6	C7
.01 Volts	5.0-08	4.5-08	1.3-07	3.8-08	6.0-08	5.8-08	1.3-08
.04	2.2-07	2.6-07	6.0	2.2-07	2.8-07	2.7-07	5.8
.08	5.6	8.4	1.6-06	8.5	8.2	7.7	1.5-07
.10	7.2	1.2-06	2.5	1.5-06	1.3-06	1.2-06	2.3
.15	1.4-06	2.9	6.6	4.8	3.8	3.4	[illegible]
.20	2.7	5.8	1.6-05	1.1-05	9.0	8.8	1.6-06
.25	4.8	1.1-05	3.6	2.2	1.8-05	2.0-05	4.0
.30	8.5	1.9	7.3	3.8	3.3	3.8	9.8
.35	1.5-05	3.5	1.4-04	6.2	6.1	7.0	2.4-05
.40	2.5	7.0	2.5	1.1-04	1.2-04	1.3-04	6.6
.45	3.9	1.9-04	5.1	2.3	3.0	2.9	2.4-04
.50	[illegible]	7.6	1.3-03	7.2	7.2	9.5	9.0
V_R							
.05 Volts	2.2-07	1.6-07	5.0-07	6.0-08	2.1-07	1.9-07	4.8-08
.10	4.4	2.5	9.4	1.2-07	3.5	3.0	8.3
.20	8.8	4.0	1.9-06	1.6	5.8	4.4	1.5-07
.30	1.4-06	5.6	2.9	1.9	7.9	5.6	2.2
.40	2.0	8.3	4.2	2.3	9.9	6.7	2.9
.50	2.6	1.1-06	5.6	2.6	1.2-06	7.7	3.7
.60	3.2	1.3	7.4	3.0	1.4	8.6	4.4

Table 16 continued

V_F/S/N	A1	A2	A3	A5	A6	A7
.01 Volts	2.7-07	2.0-08	7.5-09	1.3-08	4.8-08	3.7-06
.04	1.1-06	8.0	4.8-08	6.5	2.7-07	2.2-05
.08	2.3	2.3-07	1.3-07	1.7-07	7.3	7.9
.10	3.0	3.8	2.1	2.6	1.2-06	1.2-04
.15	5.0	9.6	5.4	6.0	3.7	3.7
.20	7.3	2.3-06	1.4-06	1.4-06	9.5	7.8
.25	1.1-05	5.0	3.4	3.6	2.0-05	1.4-03
.30	1.6	1.1-05	8.6	9.6	3.9	2.3
.35	2.7	2.8	2.4-05	2.5-05	8.0	3.4
.40	6.6	7.4	6.6	7.7	1.6-04	4.7
.45	2.3-04	2.5-04	2.3-04	2.8-04	4.2	6.3
.50	1.1-03	1.3-03	1.1-03	1.1-03	1.3-03	9.0
V_R						
.05 Volts	1.2-06	4.5-08	3.0-08	6.5-08	1.2-07	8.2-06
.10	2.5	7.0	4.8	1.1-07	1.9	1.2-05
.20	5.7	1.1-07	8.0	1.8	2.9	1.4
.30	9.4	1.6	1.1-07	2.5	3.7	1.7
.40	1.4-05	2.2	1.4	3.3	4.6	2.0
.50	1.9	2.7	1.6	3.9	5.3	2.3
.60	2.5	3.4	1.9	4.6	6.3	2.7

Table 16 continued

V_F/S/N	B1	B2	B3	B4	B5	B6	B7
.01 Volts	5.2-06	4.5-08	6.0-07	5.5-08	1.3-08	1.8-06	1.1-05
.04	2.1-05	2.1-07	4.5-06	2.9-07	5.3	1.1-05	2.8
.06	6.9	5.6	1.5-05	9.1	1.5-07	3.4	1.7-04
.10	1.1-04	1.2-06	2.5	1.5-06	2.2	5.8	5.7
.15	3.1	3.8	7.0	4.1	5.5	1.5-04	9.5
.20	7.3	1.1-05	1.6-04	1.1-05	1.4-06	3.5	2.4-03
.25	[illegible]	2.6	3.1	2.4	3.5	6.4	4.8
.30	2.4	5.1	5.2	4.8	9.2	1.1-03	8.2
.35	3.5	1.0-04	8.1	6.9	2.5-05	1.6	1.2-02
.40	5.0	1.8	1.3-03	1.7-04	7.5	2.3	1.7
.45	6.9	3.3	1.9	3.8	2.9-04	3.4	2.3
.50	9.8	1.1-03	2.4	1.3-03	1.3-03	5.4	
V_R							
.05 Volts	1.3-05	1.7-07	1.7-06	1.9-07	4.5-08	3.3-06	7.1-05
.10	2.2	1.8	2.7	3.1	7.8	5.2	9.8
.20	4.6	2.6	4.5	4.5	1.3-07	7.7	1.4-04
.30	6.9	3.8	5.9	5.7	1.7	9.9	1.7
.40	9.7	4.7	7.3	6.5	2.0	1.0-05	1.9
.50	1.3-04	6.0	8.7	7.3	2.3	1.1	2.0
.60	1.6	6.7	1.0-05	8.3	2.7	1.1	2.2

Table 16 continued

V_F/S/N	A8	A9	A10	A11	A12	A13
.01 Volts	1.2-05	2.0-06	1.5-08	2.5-06	6.3-07	5.5-04
.04	6.6	1.0-05	4.3	1.4-05	3.9-06	2.7-03
.08	2.0-04	3.8	1.1-07	4.8	1.3-05	7.4
.10	3.2	6.1	1.6	7.7	2.2	1.1-02
.15	8.2	1.8-04	3.6	2.2-04	6.4	2.1
.20	1.7-03	4.4	8.6	4.5	1.4-04	
.25	2.9	8.3	2.1-06	8.3	2.7	
.30	4.4	1.5-03	5.4	1.3-03	4.6	
.35	6.1	2.2	1.6-05	2.0	7.2	
.40	8.4	3.3	5.2	2.8	1.1-03	
.45	1.1-02	4.6	2.1-04	3.8	1.7	
.50	1.4	7.1	1.0-03	5.3	3.0	
V_R						
.05 Volts	2.9-05	3.3-06	3.3-08	5.1-06	2.0-06	1.5-03
.10	4.1	5.0	5.5	1.0-05	3.2	2.0
.20	5.5	7.2	9.5	1.4	4.6	2.6
.30	6.9	8.6	1.3-07	1.7	6.0	3.0
.40	8.1	9.6	1.7	2.1	6.9	3.5
.50	9.2	1.1-05	2.7	2.3	7.3	3.9
.60	1.0-04	1.1	3.3	2.5	7.6	4.3

Table 16 continued

V_F/S/N	B8	B9	B10	B11	B12
.01 Volts	2.0-07	2.7-07	1.2-05	3.8-05	2.5-08
.04	9.8	1.1-06	6.6	2.1-04	1.1-07
.08	3.0-06	2.8	2.3-04	7.2	2.7
.10	4.8	4.1	3.7	1.7-03	4.1
.15	1.3-05	9.7	9.7	3.3	1.0-06
.20	3.2	2.2-05	2.0-03	6.8	2.6
.25	6.6	4.2	3.4	1.1-02	6.4
.30	1.2-04	7.4	5.1		1.5-05
.35	2.1	1.3-04	7.2		3.3
.40	3.5	2.4	9.5		8.2
.45	6.8	5.2	1.2-02		2.6-04
.50	1.8-03	1.6-03	1.6		1.4-03
V_R					
.05 Volts	6.4-07	1.2-06	2.9-05	8.3-05	1.3-07
.10	1.3-06	2.0	4.3	1.2-04	2.5
.20	2.8	4.2	6.3	1.6	5.3
.30	4.9	6.6	7.9	1.7	8.6
.40	7.5	9.4	8.1	1.9	1.2-06
.50	1.1-05	1.3-05	8.3	2.0	1.5
.60	1.4	1.6	8.6	2.1	1.9

Table 17

SPECTRAL SENSITIVITY

RANGE-1

CELL NAME	A1	A10	A11	A12	A13	A2	A3
W.L. (MICRON)							
.41	.122	.134	.120	.131	.000	.119	.126
.45	.271	.290	.264	.289	.000	.272	.284
.50	.382	.404	.386	.402	.000	.393	.403
.55	.437	.446	.432	.447	.000	.440	.448
.60	.483	.512	.499	.512	.000	.510	.515
.65	.492	.505	.497	.507	.000	.506	.511
.70	.523	.531	.525	.536	.000	.534	.539
.75	.552	.608	.562	.572	.000	.571	.577
.80	.827	.892	.670	.685	.000	.665	.890
.85	.624	.633	.625	.634	.000	.635	.642
.90	.625	.602	.595	.607	.000	.606	.611
.95	.565	.592	.579	.587	.000	.564	.605
1.05	.240	.244	.230	.240	.000	.240	.251

Table 17 continued

SPECTRAL SENSITIVITY

HAMCB-1

CELL NAME	A4	A5	A6	A7	A8	A9	B1
W.L. (MICRON)							
.41	.000	.133	.121	.115	.115	.124	.107
.45	.000	.295	.277	.268	.259	.275	.266
.50	.000	.413	.396	.389	.376	.393	.388
.55	.000	.454	.442	.439	.415	.447	.446
.60	.000	.516	.512	.508	.486	.512	.503
.65	.000	.512	.505	.501	.510	.506	.507
.70	.000	.538	.533	.531	.508	.537	.535
.75	.000	.575	.579	.565	.548	.576	.567
.80	.000	.882	.869	.870	.834	.862	.833
.85	.000	.630	.632	.629	.599	.641	.627
.90	.000	.613	.605	.605	.576	.628	.615
.95	.000	.593	.582	.579	.546	.604	.570
1.05	.000	.233	.233	.231	.201	.243	.221

CELL NAME	B5	B6	B7	B8	B9	X1	X2
W.L. (MICRON)							
.41	.122	.127	.126	.135	.125	.117	.126
.45	.277	.286	.277	.293	.283	.269	.279
.50	.394	.406	.391	.407	.404	.381	.389
.55	.441	.455	.462	.456	.453	.430	.437
.60	.505	.520	.494	.520	.517	.462	.477
.65	.501	.475	.497	.515	.513	.472	.487
.70	.525	.502	.528	.542	.538	.516	.516
.75	.557	.536	.566	.573	.574	.564	.565
.80	.853	.877	.851	.878	.878	.782	.782
.85	.613	.639	.624	.639	.639	.613	.609
.90	.586	.620	.620	.614	.618	.639	.619
.95	.544	.582	.583	.575	.560	.601	.560
1.05	.209	.233	.235	.229	.236	.237	.206

CELL NAME	B10	B11	B12	B13	B2	B3	B4
W.L. (MICRON)							
.41	.122	.124	.119	.126	.132	.128	.128
.45	.277	.277	.273	.282	.289	.284	.285
.50	.401	.394	.399	.404	.408	.402	.400
.55	.453	.453	.452	.453	.455	.447	.448
.60	.519	.510	.509	.515	.519	.516	.509
.65	.514	.506	.513	.514	.514	.507	.509
.70	.543	.538	.542	.540	.541	.534	.536
.75	.579	.571	.560	.575	.575	.566	.531
.80	.864	.875	.870	.882	.861	.866	.809
.85	.643	.634	.645	.640	.637	.629	.594
.90	.635	.622	.635	.624	.615	.601	.576
.95	.595	.576	.605	.593	.573	.565	.569
1.05	.236	.237	.251	.250	.222	.225	.227

CELL NAME	X3	X4	X5	X6	X7	X8
W.L. (MICRON)						
.41	.126	.121	.125	.120	.125	.000
.45	.279	.266	.275	.275	.276	.000
.50	.383	.377	.391	.392	.394	.000
.55	.431	.427	.440	.442	.454	.000
.60	.476	.470	.501	.481	.474	.000
.65	.485	.492	.534	.494	.532	.000
.70	.511	.483	.565	.521	.569	.000
.75	.557	.528	.611	.560	.620	.000
.80	.785	.800	.846	.797	.864	.000
.85	.606	.617	.660	.614	.650	.000
.90	.615	.631	.687	.625	.664	.000
.95	.556	.586	.645	.571	.641	.000
1.05	.210	.230	.258	.221	.252	.000

Table 18

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

HAMCB-2

CELL NAME	1B1	1B2	1T1	1T2	2T1	2T2	3T1
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.061	.061	.062	.062	.062	.062	.067
B.D.RHO(OHM-CM)	1.989	1.989	3.272	3.272	2.172	2.172	2.135
A.D.R-SQR(OHM)	45.320	40.768	41.241	.000	.000	.000	43.507
AM0 VOC (MV)	580.000	.000	.000	.000	.000	.000	579.000
AM0 ISC (MA)	135.000	.000	.000	.000	.000	.000	136.000
AM0 VMP (MV)	475.000	.000	.000	.000	.000	.000	479.000
AM0 IMP (MA)	127.000	.000	.000	.000	.000	.000	127.000
AM0 FILL FCTR	.770	.000	.000	.000	.000	.000	.773
AM0 EFFICIENCY	.111	.000	.000	.000	.000	.000	.112
AM1 VOC (MV)	580.000	.000	.000	.000	.000	.000	580.000
AM1 ISC (MA)	119.000	.000	.000	.000	.000	.000	120.000
AM1 VMP (MV)	475.000	.000	.000	.000	.000	.000	482.000
AM1 IMP (MA)	113.000	.000	.000	.000	.000	.000	111.000
AM1 FILL FCTR	.778	.000	.000	.000	.000	.000	.769
AM1 EFFICIENCY	.134	.000	.000	.000	.000	.000	.134
AM1 EFF/AM0 EFF	1.204	.000	.000	.000	.000	.000	1.190
WHEN BROKEN	0	CHEM.POL.	AR.COATER	HOT PLATE	HOT PLATE	SCRIB.I.D.	0

CELL NAME	3T2	5T1	5T2	7B1	7B2	7B3	7B4
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.067	.061	.061	.062	.062	.062	.062
B.D.RHO(OHM-CM)	2.135	2.017	2.017	1.605	1.605	1.605	1.605
A.D.R-SQR(OHM)	.000	39.202	40.335	36.256	37.616	32.177	35.803
AM0 VOC (MV)	.000	.000	575.000	570.000	574.000	582.000	551.000
AM0 ISC (MA)	.000	.000	132.000	123.000	128.000	132.000	116.000
AM0 VMP (MV)	.000	.000	472.000	465.000	473.000	477.000	449.000
AM0 IMP (MA)	.000	.000	124.000	114.000	121.000	126.000	109.000
AM0 FILL FCTR	.000	.000	.771	.756	.779	.782	.766
AM0 EFFICIENCY	.000	.000	.108	.098	.106	.111	.090
AM1 VOC (MV)	.000	.000	575.000	569.000	573.000	581.000	550.000
AM1 ISC (MA)	.000	.000	115.000	107.000	112.000	115.000	101.000
AM1 VMP (MV)	.000	.000	477.000	465.000	474.000	482.000	450.000
AM1 IMP (MA)	.000	.000	108.000	99.000	106.000	108.000	95.000
AM1 FILL FCTR	.000	.000	.779	.756	.783	.779	.770
AM1 EFFICIENCY	.000	.000	.129	.115	.126	.130	.107
AM1 EFF/AM0 EFF	.000	.000	1.191	1.175	1.188	1.172	1.182
WHEN BROKEN	HOT PLATE	BACK ETCH	0	0	0	0	0

CELL NAME	X2	X3	X4	X5	X6	X7	X8
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.028	.028	.028	.028	.028	.028	.028
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	42.146	44.867	42.601	40.335	42.146	39.882	41.241
AM0 VOC (MV)	581.000	583.000	581.000	583.000	583.000	577.000	581.000
AM0 ISC (MA)	139.000	139.000	140.000	133.000	138.000	130.000	135.000
AM0 VMP (MV)	480.000	485.000	474.000	484.000	479.000	456.000	474.000
AM0 IMP (MA)	132.000	129.000	130.000	126.000	130.000	114.000	127.000
AM0 FILL FCTR	.785	.772	.758	.786	.774	.693	.767
AM0 EFFICIENCY	.117	.116	.114	.113	.115	.096	.111
AM1 VOC (MV)	584.000	584.000	582.000	584.000	583.000	.000	581.000
AM1 ISC (MA)	122.000	121.000	123.000	117.000	121.000	.000	118.000
AM1 VMP (MV)	487.000	482.000	483.000	485.000	484.000	.000	477.000
AM1 IMP (MA)	115.000	115.000	113.000	110.000	115.000	.000	111.000
AM1 FILL FCTR	.786	.784	.762	.781	.789	.000	.772
AM1 EFFICIENCY	.140	.139	.136	.133	.139	.000	.132
AM1 EFF/AM0 EFF	1.196	1.199	1.198	1.184	1.209	.000	1.190
WHEN BROKEN	0	0	0	0	0	0	0

Table 18 continued

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

HAMCB-2

CELL NAME	9B1	9B2	9M1	9M2	9T1	9T2	X1
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.061	.061	.062	.062	.061	.061	.028
B.D.RHO(OHM-CM)	1.658	1.658	1.523	1.523	2.044	2.044	.000
A.D.R-SQR(OHM)	43.054	.000	39.882	39.202	39.882	38.522	57.330
AM0 VOC (MV)	559.000	.000	561.000	562.000	.000	561.000	560.000
AM0 ISC (MA)	116.000	.000	130.000	131.000	.000	130.000	143.000
AM0 VMP (MV)	454.000	.000	461.000	461.000	.000	482.000	475.000
AM0 IMP (MA)	110.000	.000	123.000	124.000	.000	124.000	134.000
AM0 FILL FCTR	.770	.000	.763	.762	.000	.791	.767
AM0 EFFICIENCY	.092	.000	.109	.110	.000	.110	.118
AM1 VOC (MV)	559.000	.000	581.000	581.000	.000	581.000	583.000
AM1 ISC (MA)	102.000	.000	114.000	115.000	.000	114.000	126.000
AM1 VMP (MV)	453.000	.000	462.000	490.000	.000	481.000	475.000
AM1 IMP (MA)	96.000	.000	106.000	107.000	.000	109.000	118.000
AM1 FILL FCTR	.763	.000	.766	.765	.000	.792	.763
AM1 EFFICIENCY	.109	.000	.130	.131	.000	.131	.140
AM1 EFF/AM0 EFF	1.178	.000	1.190	1.189	.000	1.167	1.191
WHEN BROKEN	0	CHEM.POL.	0	0	SPINNER	0	0

Table 19

SPECTRAL SENSITIVITY

HAMCB-2

CELL NAME	1B1	1B2	1T1	1T2	2T1	2T2	3T1
W.L. (MICRON)							
.41	.128	.000	.000	.000	.000	.000	.149
.45	.308	.000	.000	.000	.000	.000	.321
.50	.437	.000	.000	.000	.000	.000	.439
.55	.495	.000	.000	.000	.000	.000	.497
.60	.522	.000	.000	.000	.000	.000	.516
.65	.540	.000	.000	.000	.000	.000	.540
.70	.562	.000	.000	.000	.000	.000	.569
.75	.602	.000	.000	.000	.000	.000	.623
.80	.621	.000	.000	.000	.000	.000	.638
.85	.612	.000	.000	.000	.000	.000	.660
.90	.612	.000	.000	.000	.000	.000	.705
.95	.271	.000	.000	.000	.000	.000	.607
1.05	.176	.000	.000	.000	.000	.000	.227

Table 19 continued

SPECTRAL SENSITIVITY

HAMCB-2

CELL NAME / W.L. (MICRON)	9B1	9B2	9M1	9M2	9T1	9T2	X1
.41	.128	.000	.127	.126	.000	.122	.147
.45	.310	.000	.304	.303	.000	.292	.310
.50	.434	.000	.422	.427	.000	.421	.414
.55	.478	.000	.463	.464	.000	.485	.456
.60	.520	.000	.501	.505	.000	.508	.485
.65	.515	.000	.522	.523	.000	.533	.506
.70	.522	.000	.539	.538	.000	.554	.534
.75	.536	.000	.570	.567	.000	.598	.575
.80	.567	.000	.602	.590	.000	.629	.623
.85	.485	.000	.590	.565	.000	.632	.631
.90	.400	.000	.567	.571	.000	.665	.660
.95	.305	.000	.473	.467	.000	.551	.625
1.05	.066	.000	.153	.149	.000	.197	.258

CELL NAME / W.L. (MICRON)	3T2	5T1	5T2	7B1	7B2	7B3	7B4
.41	.000	.000	.125	.116	.122	.122	.123
.45	.000	.000	.295	.301	.305	.305	.306
.50	.000	.000	.42[illegible]	.421	.428	.434	.422
.55	.000	.000	.495	.465	.460	.484	.475
.60	.000	.000	.517	.478	.469	.502	.493
.65	.000	.000	.54[illegible]	.464	.499	.513	.504
.70	.000	.000	.571	.480	.497	.517	.512
.75	.000	.000	.621	.485	.506	.529	.523
.80	.000	.000	.641	.475	.467	.535	.517
.85	.000	.000	.646	.429	.454	.501	.477
.90	.000	.000	.673	.366	.395	.444	.427
.95	.000	.000	.547	.251	.296	.338	.304
1.05	.000	.000	.166	.061	.076	.091	.085

CELL NAME / W.L. (MICRON)	X2	X3	X4	X5	X6	X7	X8
.41	.121	.139	.136	.137	.143	.118	.133
.4[illegible]	.280	.309	.304	.292	.326	.293	.308
.50	.396	.424	.420	.365	.449	.419	.425
.55	.450	.470	.472	.424	.459	.470	.487
.60	.479	.500	.500	.453	.476	.446	.502
.65	.504	.521	.522	.478	.504	.454	.530
.70	.530	.549	.550	.510	.526	.482	.551
.75	.570	.591	.590	.554	.576	.520	.547
.80	.605	.632	.626	.605	.621	.574	.569
.85	.626	.643	.646	.631	.649	.585	.593
.90	.664	.679	.663	.691	.710	.604	.634
.95	.624	.644	.629	.642	.662	.537	.569
1.05	.258	.269	.251	.268	.275	.204	.215

Table 20

DARK CURRENT DENSITY, RUN HamcB-2

V_F/S/N	C1	C2	C3	C4	C5	C6	C7	C8
.01 Volts	1.5-07	2.3-08	6.6-06	1.6-07	1.7-06	1.8-06	3.8-06	1.7-06
.04	5.7	1.4-07	2.6-05	6.8	4.4	7.4	1.9-05	6.8
.08	1.2-06	5.3	5.3	1.9-06	8.8	1.4-05	3.1	1.4-05
.10	1.5	9.4	6.7	2.9	1.1-05	1.8	4.0	1.8
.15	2.7	3.1-06	1.1-04	9.1	1.7	2.7	6.2	3.1
.20	4.8	8.3	1.5	2.6-05	2.[illegible]	3.6	9.0	5.0
.25	9.2	1.8-05	1.9	6.5	3.6	4.7	1.3-04	7.9
.30	2.0-05	3.5	2.4	1.[illegible]-04	5.2	6.1	1.9	1.2-04
.35	4.7	6.2	2.8	2.6	7.9	8.5	3.0	1.9
.40	1.2-04	1.2-04	3.1	4.6	1.4-04	1.4-04	5.1	2.7
.45	3.6	2.6	3.9	[illegible].4	3.0	3.0	9.7	4.1
.50	1.2-03	9.7	4.6	[illegible].8-03	1.0-03	1.0-03	2.2-03	6.5
V_R								
.05 Volts	1.0-06	6.3-08	3.3-05	[illegible].2-07	5.4-06	9.5-06	1.9-05	8.5-05
.10	2.2	8.8	6.6	[illegible].5-06	1.1-05	1.9-05	3.8	1.7-05
.20	5.0	1.2-07	1.3-04	3.4	2.1	4.0	7.5	3.4
.30	8.1	1.4	2.0	5.6	3.2	6.3	1.1-04	5.1
.40	1.2-05	1.5	2.6	[illegible].1	4.3	8.7	1.5	6.9
.50	1.5	1.7	3.4	[illegible].1-05	5.4	1.1-04	1.9	8.5
.60	2.0	1.9	4.2	1.3	6.4	1.4	2.3	1.0-04

V_F/S/N	3T1	5T2	9T2	9M1	9M2	1B1	7B1	7B2	7B3	7B4	9B1
.01 Volts	1.6-06	1.3-08	7.5-09	5.8-08	3.5-08	6.8-08	7.5-09	5.0-09	2.5-08	3.5-08	3.0-07
.04	1.0-05	5.3	4.3-08	2.3-07	2.0-07	3.1-07	4.5-08	2.8-08	1.1-07	1.9-07	1.0-06
.08	2.9	1.6-07	1.3-07	4.9	6.6	7.7	1.3-07	8.0	2.9	6.1	3.9
.10	4.2	2.5	2.0	6.4	1.0-06	1.1-06	2.1	1.2-07	4.4	1.0-06	5.7
.15	8.3	7.3	5.4	1.1-06	2.6	2.7	6.0	3.2	1.1-06	3.3	1.3-05
.20	1.4-04	2.1-06	1.4-06	2.0	5.8	6.0	1.8-06	8.9	3.0	9.1	2.3
.25	2.0	5.7	3.2	3.8	1.2-05	1.2-05	5.3	2.5-06	7.1	2.2-05	3.9
.30	2.7	1.5-05	7.7	8.6	2.4	2.7	1.6-05	8.4	1.8-05	4.8	6.5
.35	3.6-04	3.8	2.0-05	2.2-05	5.1	6.0	5.2	3.1-05	4.7	1.1-04	1.2-04
.40	4.9	1.0-04	5.9	6.6	1.2-04	1.4-04	1.8-04	1.2-04	1.4-04	3.0	2.4
.45	7.3	3.4	2.2-04	2.4-04	3.4	4.2	6.7	5.2	4.5	1.0-03	6.7
.50	1.6-03	1.3-03	1.0-03	9.8	1.3-03	1.5-03	2.5-03	2.1-03	1.6-03	3.9	2.2-03
V_R											
.05 Volts	5.2-06	2.5-08	2.6-08	2.8-07	9.0-08	1.6-07	3.5-08	2.5-08	6.5-08	1.5-07	1.3-06
.10	7.4	4.5	4.9	5.5	1.3-07	2.9	6.8	5.0	1.1-07	2.8	2.5
.20	1.0-05	7.0	7.0	1.1-06	1.8	5.8	1.3-07	1.1-07	1.8	5.5	5.8
.30	1.4	9.5	9.5	1.7	2.2	9.2	2.2	2.0	2.4	9.9	1.0-05
.40	1.7	1.2-07	1.2-07	2.4	2.5	1.3-06	3.3	3.0	3.0	1.5-06	1.6
.50	2.0	1.5	1.4	3.0	2.8	1.8	4.7	4.4	3.5	2.2	2.3
.60	2.4	1.7	1.7	3.7	3.2	2.3	6.6	6.0	4.1	3.0	3.1

Table 21

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

HAMCO-1

CELL NAME	1B1	1B2	1T1	1T2	1T3	3B1	3B2
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.060	.060	.061	.061	.061	.061	.061
B.D.RHO(OHM-CM)	.189	.189	.332	.332	.332	.221	.221
A.D.R-SOR(OHM)	53.478	53.931	49.652	53.478	51.665	55.290	57.103
AM0 VOC (MV)	487.000	.000	596.000	595.000	571.000	417.000	.000
AM0 ISC (MA)	117.000	.000	150.000	147.000	138.000	116.000	.000
AM0 VMP (MV)	325.000	.000	491.000	489.000	469.000	250.000	.000
AM0 IMP (MA)	89.000	.000	132.000	125.000	123.000	87.000	.000
AM0 FILL FCTR	.508	.000	.725	.699	.732	.450	.000
AM0 EFFICIENCY	.053	.000	.120	.113	.107	.040	.000
AM1 VOC (MV)	.000	.000	.000	.000	570.000	.000	.000
AM1 ISC (MA)	.000	.000	.000	.000	119.000	.000	.000
AM1 VMP (MV)	.000	.000	.000	.000	468.000	.000	.000
AM1 IMP (MA)	.000	.000	.000	.000	106.000	.000	.000
AM1 FILL FCTR	.000	.000	.000	.000	.731	.000	.000
AM1 EFFICIENCY	.000	.000	.000	.000	.124	.000	.000
AM1 EFF/AM0 EFF	.000	.000	.000	.000	1.164	.000	.000
WHEN BROKEN		0	0	0	0	0	0

CELL NAME	3T1	3T2	5B1	5B2	5T1	5T2	7B1
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.070	.070	.061	.061	.061	.061	.061
B.D.RHO(OHM-CM)	.222	.222	.249	.249	.249	.249	.221
A.D.R-SOR(OHM)	53.024	53.931	54.364	56.650	56.650	54.384	57.103
AM0 VOC (MV)	.000	601.000	560.000	577.000	557.000	521.000	575.000
AM0 ISC (MA)	.000	147.000	131.000	134.000	144.000	146.000	136.000
AM0 VMP (MV)	.000	495.000	462.000	475.000	385.000	338.000	470.000
AM0 IMP (MA)	.000	131.000	120.000	123.000	106.000	112.000	124.000
AM0 FILL FCTR	.000	.734	.756	.756	.509	.498	.745
AM0 EFFICIENCY	.000	.120	.102	.108	.075	.070	.109
AM1 VOC (MV)	.000	596.000	557.000	576.000	.000	.000	573.000
AM1 ISC (MA)	.000	127.000	112.000	116.000	.000	.000	117.000
AM1 VMP (MV)	.000	493.000	459.000	475.000	.000	.000	472.000
AM1 IMP (MA)	.000	116.000	104.000	105.000	.000	.000	108.000
AM1 FILL FCTR	.000	.769	.765	.746	.000	.000	.760
AM1 EFFICIENCY	.000	.145	.119	.125	.000	.000	.127
AM1 EFF/AM0 EFF	.000	1.214	1.165	1.155	.000	.000	1.183
WHEN BROKEN	?	0	0	0	0	0	PRINTING

CELL NAME	7T1	7T2	9M1	9M2	9M3	9T1	9T2
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.061	.061	.060	.060	.060	.061	.061
B.D.RHO(OHM-CM)	.221	.221	.216	.216	.216	.221	.221
A.D.R-SOR(OHM)	56.650	54.384	53.024	54.384	54.364	57.556	53.024
AM0 VOC (MV)	601.000	594.000	597.000	595.000	404.000	533.000	602.000
AM0 ISC (MA)	147.000	143.000	140.000	142.000	138.000	144.000	147.000
AM0 VMP (MV)	504.000	488.000	500.000	500.000	250.000	300.000	505.000
AM0 IMP (MA)	135.000	115.000	129.000	124.000	99.000	73.000	135.000
AM0 FILL FCTR	.770	.661	.772	.734	.444	.285	.770
AM0 EFFICIENCY	.126	.104	.119	.115	.046	.040	.126
AM1 VOC (MV)	600.000	.000	595.000	593.000	.000	.000	599.000
AM1 ISC (MA)	127.000	.000	122.000	122.000	.000	.000	127.000
AM1 VMP (MV)	504.000	.000	497.000	491.000	.000	.000	496.000
AM1 IMP (MA)	118.000	.000	111.000	108.000	.000	.000	117.000
AM1 FILL FCTR	.760	.000	.760	.733	.000	.000	.763
AM1 EFFICIENCY	.149	.000	.136	.133	.000	.000	.145
AM1 EFF/AM0 EFF	1.183	.000	1.157	1.157	.000	.000	1.152
WHEN BROKEN	0	0	0	0	0	0	0

Table 21 continued

RESISTIVITY AND ILLUMINATED CHARACTERISTICS

HAMCO-1

CELL NAME	X1	X2	X3	X4	X5	X6	X7
AREA (CM2)	4.000	4.000	4.000	4.000	4.000	4.000	4.000
THICK (CM)	.023	.023	.023	.023	.023	.023	.023
B.D.RHO(OHM-CM)	.000	.000	.000	.000	.000	.000	.000
A.D.R-SQR(OHM)	53.024	50.758	51.665	52.116	54.384	53.931	52.571
AM0 VOC (MV)	560.000	.000	561.000	.000	572.000	.000	577.000
AM0 ISC (MA)	142.000	.000	142.000	.000	142.000	.000	142.000
AM0 VMP (MV)	480.000	.000	466.000	.000	475.000	.000	478.000
AM0 IMP (MA)	131.000	.000	131.000	.000	129.000	.000	130.000
AM0 FILL FCTR	.763	.000	.772	.000	.754	.000	.755
AM0 EFFICIENCY	.116	.000	.116	.000	.113	.000	.115
AM1 VOC (MV)	575.000	.000	561.000	.000	577.000	.000	577.000
AM1 ISC (MA)	123.000	.000	123.000	.000	124.000	.000	124.000
AM1 VMP (MV)	473.000	.000	461.000	.000	472.000	.000	470.000
AM1 IMP (MA)	115.000	.000	114.000	.000	116.000	.000	116.000
AM1 FILL FCTR	.769	.000	.767	.000	.765	.000	.762
AM1 EFFICIENCY	.136	.000	.137	.000	.137	.000	.136
AM1 EFF/AM0 EFF	1.170	.000	1.165	.000	1.209	.000	1.187
WHEN BROKEN	0	PRINTING	0	7	0	7	0

CELL NAME	X8
AREA (CM2)	4.000
THICK (CM)	.023
B.D.RHO(OHM-CM)	.000
A.D.R-SQR(OHM)	51.665
AM0 VOC (MV)	.000
AM0 ISC (MA)	.000
AM0 VMP (MV)	.000
AM0 IMP (MA)	.000
AM0 FILL FCTR	.000
AM0 EFFICIENCY	.000
AM1 VOC (MV)	.000
AM1 ISC (MA)	.000
AM1 VMP (MV)	.000
AM1 IMP (MA)	.000
AM1 FILL FCTR	.000
AM1 EFFICIENCY	.000
AM1 EFF/AM0 EFF	.000

WHEN BROKEN

Table 22

SPECTRAL SENSITIVITY

HAMCO-1

CELL NAME	1E1	1E2	1T1	1T2	1T3	3B1	3B2
W.L. (MICRON)							
.41	.123	.073	.126	.136	.117	.103	.136
.45	.268	.171	.271	.269	.257	.254	.254
.50	.372	.250	.392	.365	.362	.365	.371
.55	.428	.282	.457	[illegible]	.438	.402	.417
.60	.451	.299	.506	.500	.472	.417	.426
.65	.465	.304	.526	.522	.494	.418	.425
.70	.494	.309	.577	.563	.525	.418	.443
.75	.499	.312	.620	.638	.559	.407	.431
.80	.495	.301	.667	.677	.579	.401	.041
.85	.463	.293	.715	.690	.552	.345	.360
.90	.461	.246	.804	.679	.551	.264	.371
.95	.345	.168	.609	.611	.483	.217	.242
1.05	.128	.061	.339	.340	.139	.065	.067

Table 22 continued

SPECTRAL SENSITIVITY

HAMCO-1

CELL NAME	3T1	3T2	5B1	5B2	5T1	5T2	7B1
W.L. (MICRON)							
.41	.141	.145	.113	.110	.125	.125	.115
.45	[illegible]	.245	.261	.251	.270	.266	.261
.50	[illegible]	.391	.376	.359	.369	.369	.376
.55	.453	.457	.422	.416	.448	.452	.405
.60	.501	.494	.448	.448	.491	.495	.458
.65	.523	.529	.455	.466	.513	.521	.467
.70	.573	.504	.401	.500	.561	.567	.495
.75	.617	.637	.435	.519	.606	.612	.497
.80	.670	.665	.470	.523	.644	.657	.503
.85	.681	.716	.417	.495	.671	.682	.444
.90	.743	.817	.427	.493	.739	.740	.427
.95	.768	.850	.306	.402	.749	.751	.294
1.05	.391	.367	.093	.115	.350	.346	.073

CELL NAME	7T1	7T2	9M1	9M2	9M3	9T1	9T2
W.L. (MICRON)							
.41	.125	.172	.105	.116	.128	.121	.160
.45	.257	.270	.243	.259	.271	.264	.301
.50	.390	.380	.374	.396	.370	.390	.398
.55	.449	.439	.459	.436	.433	.452	.457
.60	.465	.470	.477	.481	.462	.505	.494
.65	.52[illegible]	.500	.496	.501	.485	.523	.516
.70	.546	.563	.521	.532	.519	.565	.575
.75	.127	.605	.550	.565	.544	.604	.613
.80	.652	.579	.590	.603	.562	.666	.660
.85	.670	.666	.576	.592	.556	.668	.665
.90	.784	.829	.539	.582	.561	.704	.748
.95	.756	.744	.515	.552	.492	.709	.727
1.05	.283	.305	.163	.212	.179	.337	.356

CELL NAME	X1	X2	X3	X4	X5	X6	X7
W.L. (MICRON)							
.41	.104	.000	.111	.137	.114	.257	.109
.45	.249	.000	.260	.281	.268	.385	.257
.50	.381	.000	.363	.399	.368	.415	.385
.55	.448	.000	.448	.463	.450	.467	.452
.60	.488	.000	.494	.507	.490	.498	.506
.65	.519	.000	.519	.530	.514	.512	.531
.70	.560	.000	.555	.581	.550	.633	.570
.75	.606	.000	.662	.630	.592	.648	.612
.80	.639	.000	.646	.681	.632	.676	.654
.85	.662	.000	.651	.704	.637	.699	.658
.90	.705	.000	.668	.776	.648	.916	.668
.95	.666	.000	.642	.812	.606	.824	.648
1.05	.277	.000	.255	.410	.236	.472	[illegible]

CELL NAME	X8
W.L. (MICRON)	
.41	.165
.45	.314
.50	.397
.55	.457
.60	.461
.65	.517
.70	.626
.75	.653
.80	.655
.85	.679
.90	.822
.95	.750
1.05	.372

Table 23

DARK CURRENT DENSITY, RUN No. [illegible]

V_F/S/N	C1	C3	C4	C5	C6	C7
.01 Volts	2.8-07	4.6-06	5.9-05	4.6-06	5.2-06	1.6-06
.04	1.4-06	1.9-05	2.4-04	1.9-05	1.8-03	5.4
.08	4.4	4.7	4.5	4.7	4.2	1.2-05
.10	7.1	7.4	5.8	7.4	5.7	1.6
.15	1.9-05	1.4-04	1.0-03	1.4-04	1.0-02	3.3
.20	3.9	2.4	1.5	2.4	1.6	5.1
.25	7.4	3.6	2.0	3.6	2.3	8.0
.30	1.2-04	5.0	2.6	5.0		1.2-04
.35	1.8	6.4	3.1	6.4		1.9
.40	3.1	8.4	3.7	8.4		3.1
.45	5.5	1.1-03	4.4	1.1-03		6.0
.50	1.4-03	2.0	5.0	2.0		1.7-03
V_R						
.05 Volts	8.4-04	9.2-06	2.5-04	9.2-06	2.3-03	6.3-06
.10	1.3-03	1.5-05	4.2	1.5-05	4.2	1.3-05
.20	2.1	2.0	8.1	2.0	8.2	2.4
.30	2.8	2.5	1.2-03	2.4	1.2-02	3.5
.40	3.6	3.1	1.6	2.9	1.6	4.5
.50	4.3	3.6	2.0	3.3	2.1	5.6
.60	5.0	4.2	2.4	3.8	2.5	6.7

Table 23 continued

V_F/S/N	7[illegible]1	7T2	7T1	9M1	9M2	9M3
.01 Volts	7.7-06	8.9-05	6.4-06	1.1-05	6.2-05	1.1-04
.04	2.6-05	3.1-04	2.3-05	4.0	1.8-04	4.7
.08	4.8	5.8	4.3	7.5	3.5	9.6
.10	6.1	7.2	5.6	9.3	4.3	1.3-03
.15	2.6-04	1.1-03	8.2	1.4-04	6.6	2.5
.20	3.5	1.5	1.1-04	1.9	8.8	4.7
.25	4.5	1.9	1.4	2.4	1.1-03	8.1
.30	5.7	2.4	1.8	3.0	1.4	1.3-02
.35	6.8	2.9	2.2	3.7	1.6	1.7
.40	8.1	3.4	3.0	4.8	1.9	2.5
.45	9.9	4.2	7.1	7.0	2.4	
.50	1.2-03	5.2	1.0-03	1.6-03	3.4	
V_R						
.05 Volts	3.0-05	3.8-04	3.2-05	4.7-05	2.0-04	5.3-04
.10		8.0	6.2	9.5	4.4	1.0-03
.20	1.2-04	1.7-03	1.3-04	2.0-04	8.9	2.0
.30	1.9	2.7	2.1	3.0	1.3-03	3.1
.40	4.1	3.8	3.0	4.1	1.8	4.1
.50	7.3	5.1	3.7	5.1	2.3	5.2
.60		6.5	5.0	6.3	2.8	6.2

Table 23 continued

V_F/S/N	3B1	3B2	5B1	5B2	5T1	5T2	3T1	3T3
.01 Volts		8.3-06	5.4-06	1.0-05	1.1-05	3.3-05	1.3-05	5.9-06
.04	6.0-05	2.7-05	2.2-05	3.7	4.6	1.4-04	5.7	2.5-05
.08	2.0-04	7.4	4.2	7.5	9.2	3.0	1.2-04	5.1
.10	3.2	9.6	5.2	9.3	1.2-04	4.0	1.5	6.4
.15	9.8	1.5-04	8.0	1.4-04	1.7	7.3	2.2	9.8
.20	2.4-03	2.1	1.1-04	2.0	2.3	1.3-03	3.1	1.3-04
.25	4.7	2.8	1.4	2.6	2.9	2.2	3.9	1.7
.30	8.0	3.4	1.8	3.2	3.4	3.7	4.8	2.2
.35	1.2-02	4.1	2.6	4.2	3.6	5.7	5.8	2.6
.40	1.8	4.9	4.5	6.0	3.9	8.4	7.5	3.1
.45	2.4	5.8	1.0-03	1.1-03	4.2	1.2-02	8.7	3.6
.50		6.5	3.7	2.9	4.5	1.6	9.9	4.2
V_R								
.05 Volts	4.7-05	4.3-05	2.7-05	5.0-05	4.6-05	1.7-04	1.1-04	3.2-05
.10	8.7	8.6	5.6	1.0-04	9.4	3.5	2.0	6.4
.20	1.7-04	1.7-04	1.2-04	2.2	1.9-04	7.1	4.7	1.3-04
.30	2.7	2.6	1.8	3.5	2.9	1.1-03	7.7	1.9
.40	3.8	3.6	2.5	4.7	3.9	1.5	1.1-03	2.6
.50	4.9	4.6	3.3	6.2	4.8	1.9	1.6	3.3
.60	6.2	5.7	4.1	7.7	5.9	2.4	2.2	4.0

8.0 FIGURES

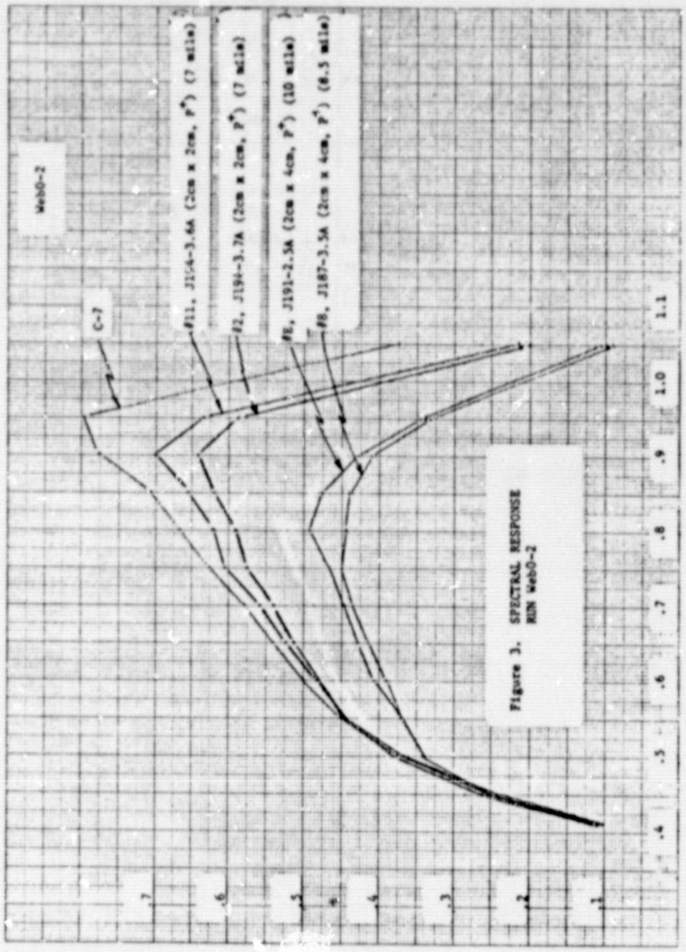

Figure 3. SPECTRAL RESPONSE RUN Web0-2

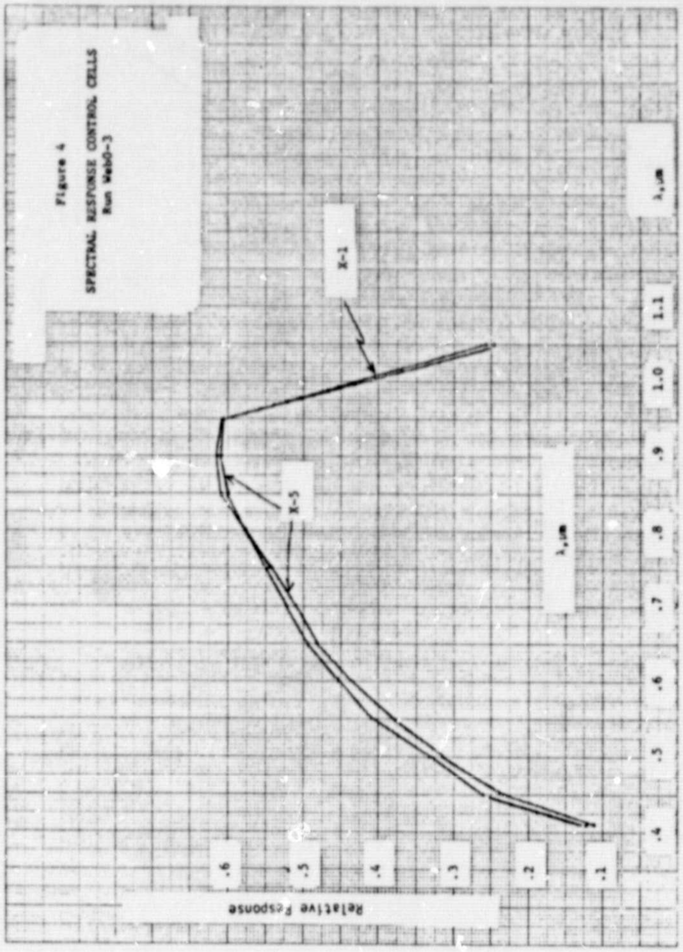

Figure 4 SPECTRAL RESPONSE CONTROL CELLS Run Web0-3

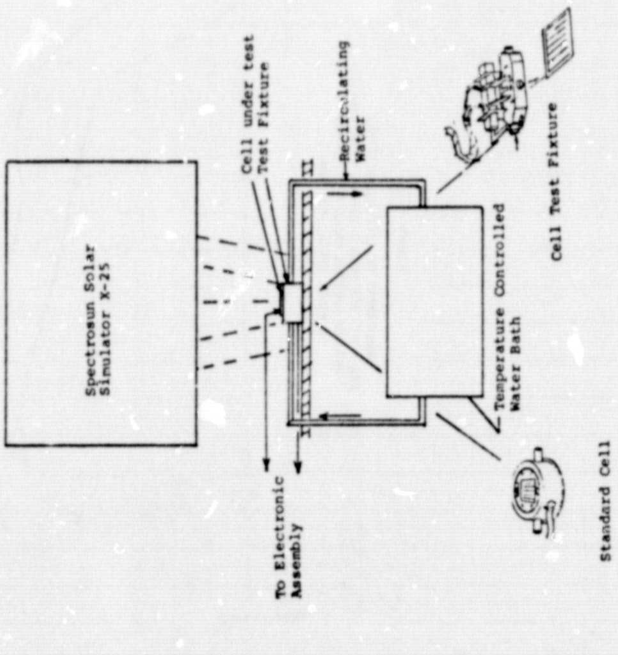

Figure 1. Schematic representation of Solar I-V Measurement System.

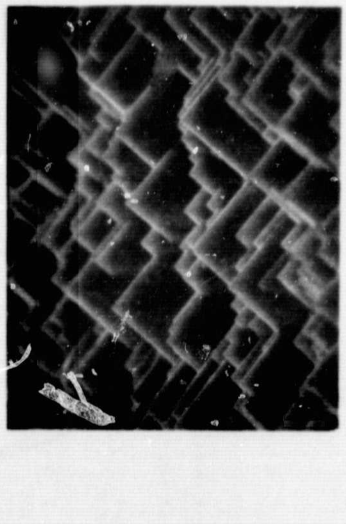

Figure 2

TEXTURED SURFACE OF SOLAR CELL
NaOH ETCHANT
SCANNING ELECTRON MICROSCOPE
SECONDARY ELECTRONS, ~50° TILT, 1500X

ORIGINAL PAGE IS OF POOR QUALITY

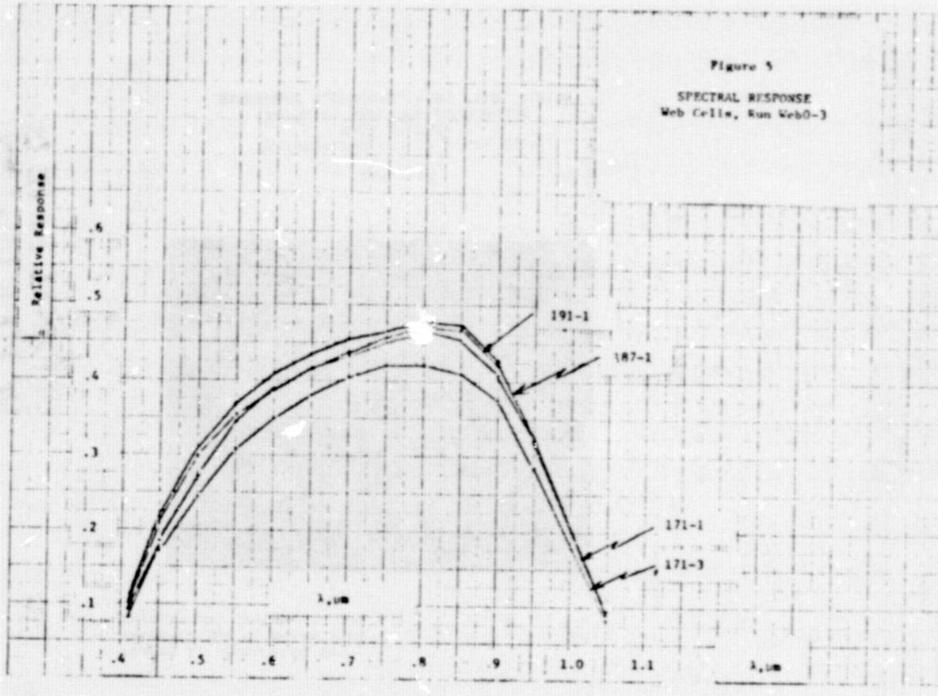

Figure 5

SPECTRAL RESPONSE
Web Cells, Run WebO-3

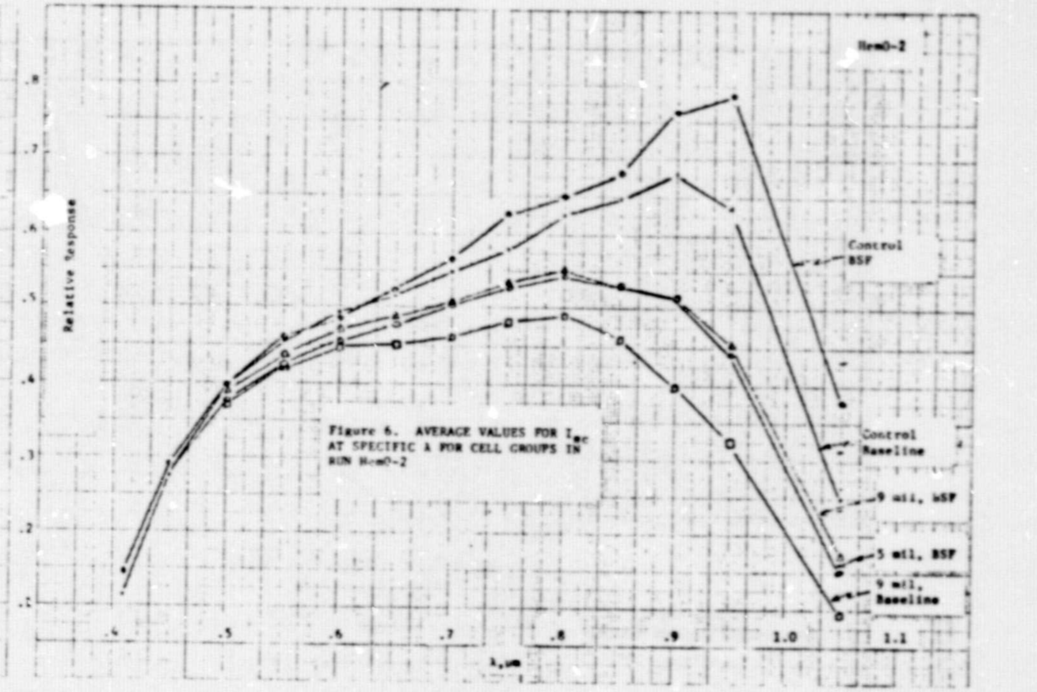

Figure 6. AVERAGE VALUES FOR I_{sc} AT SPECIFIC λ FOR CELL GROUPS IN RUN HemO-2

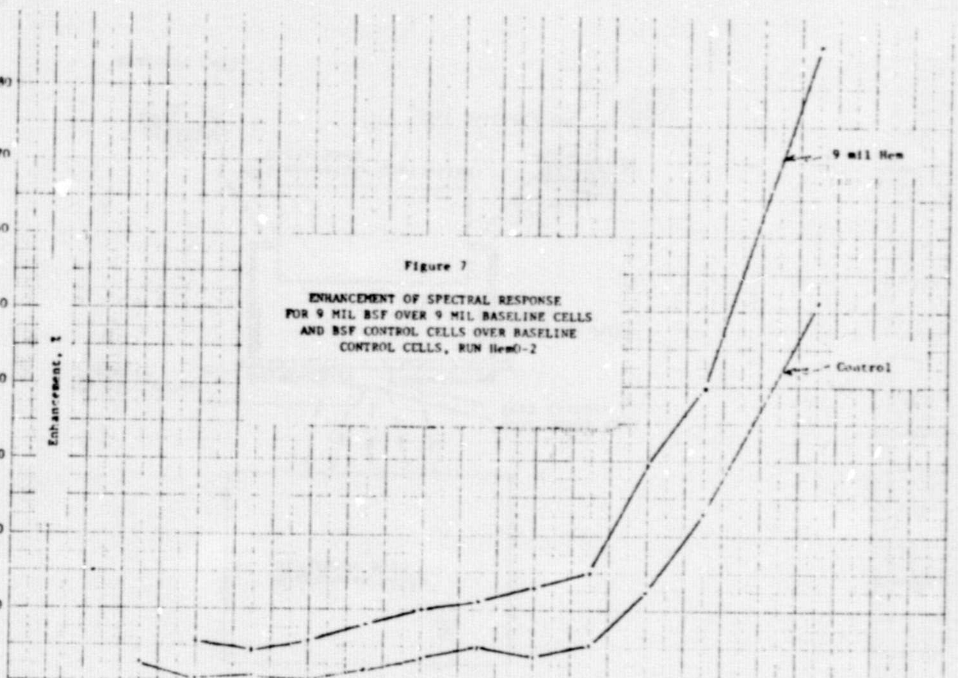

Figure 7

ENHANCEMENT OF SPECTRAL RESPONSE FOR 9 MIL BSF OVER 9 MIL BASELINE CELLS AND BSF CONTROL CELLS OVER BASELINE CONTROL CELLS, RUN HemO-2

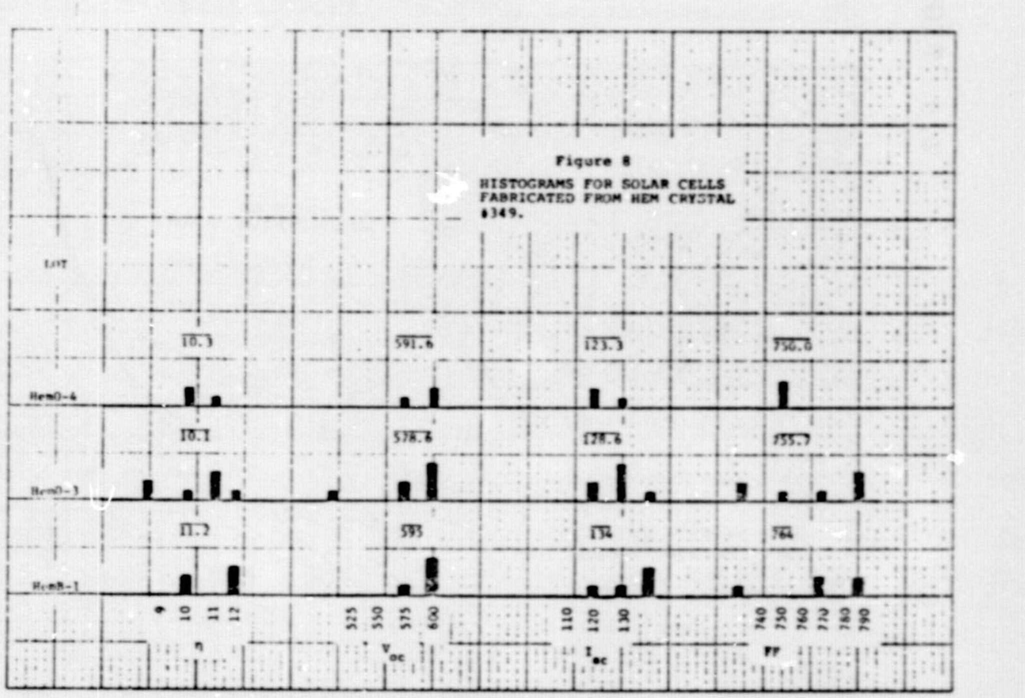

Figure 8

HISTOGRAMS FOR SOLAR CELLS FABRICATED FROM HEM CRYSTAL #349.

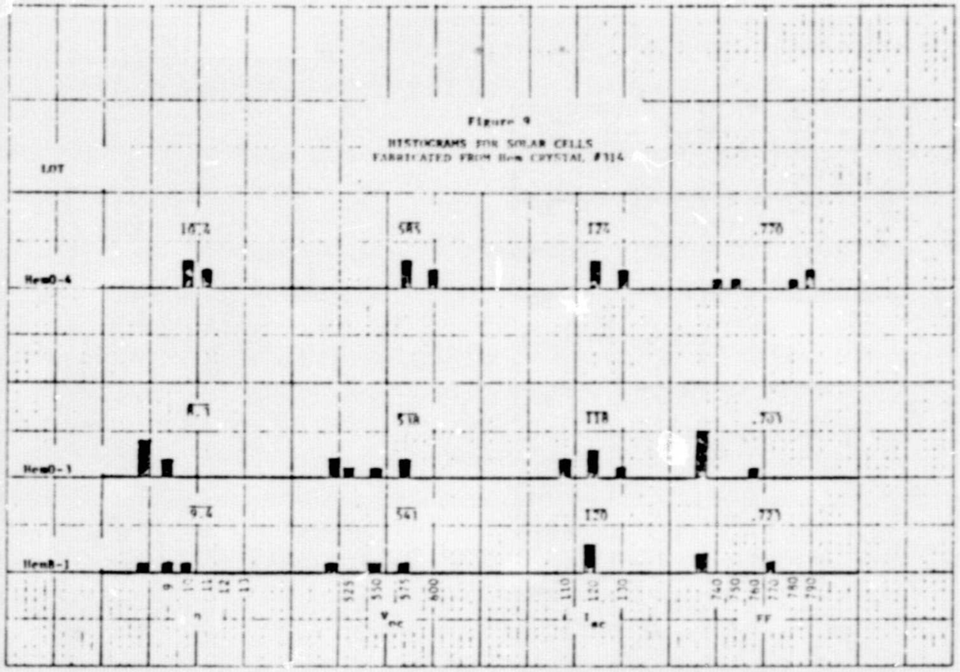

Figure 9

HISTOGRAMS FOR SOLAR CELLS FABRICATED FROM Hem CRYSTAL #314

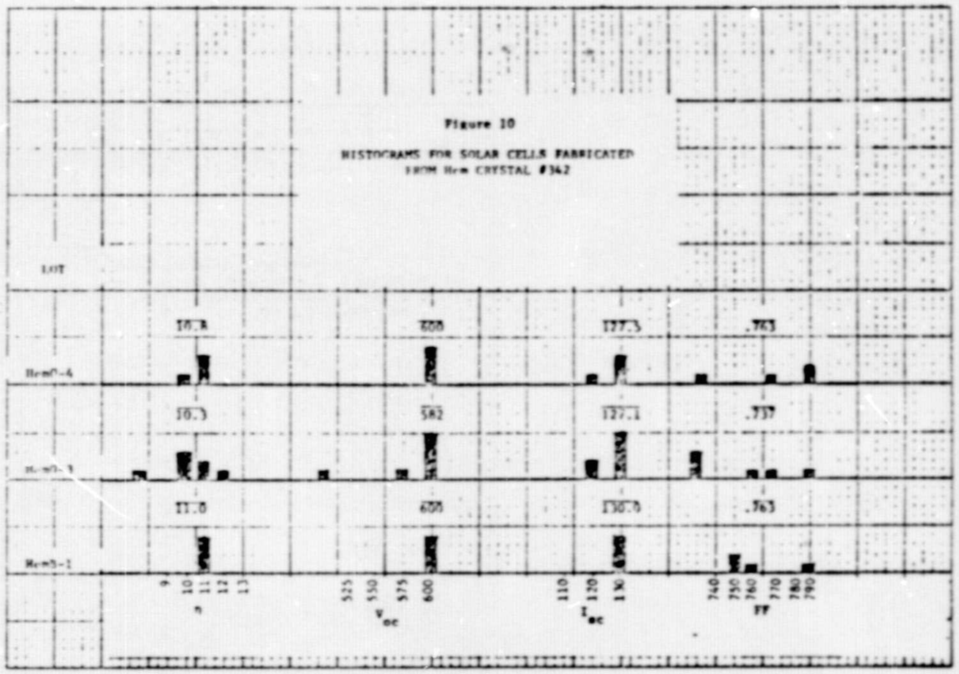

Figure 10

HISTOGRAMS FOR SOLAR CELLS FABRICATED FROM Hem CRYSTAL #342

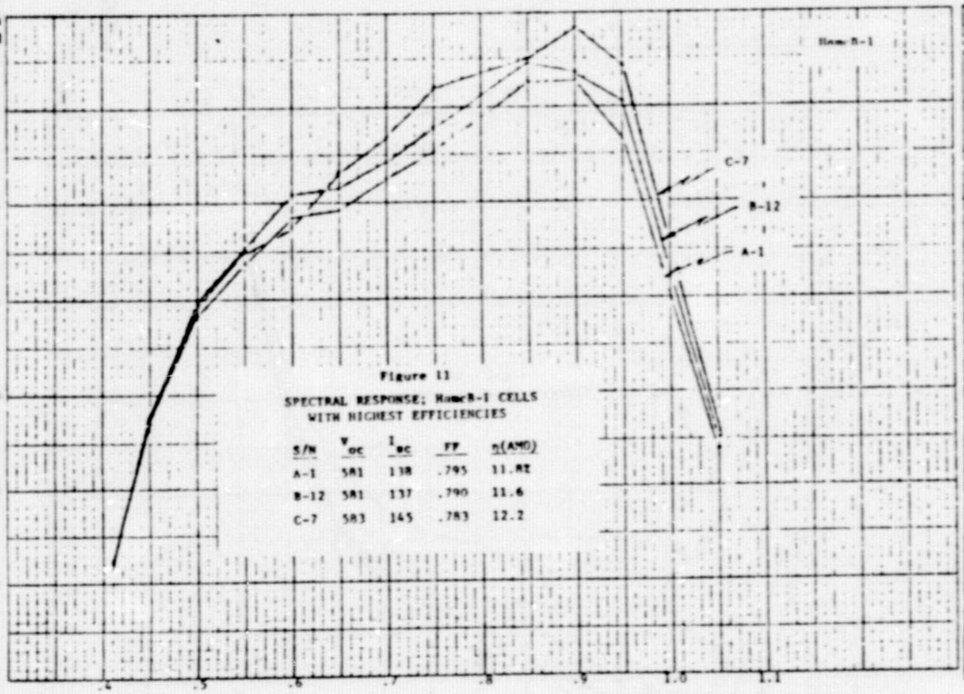

Figure 11

SPECTRAL RESPONSE; HemB-1 CELLS WITH HIGHEST EFFICIENCIES

S/N	V_{oc}	I_{sc}	FF	η(AMO)
A-1	581	138	.795	11.8%
B-12	581	137	.790	11.6
C-7	583	145	.783	12.2

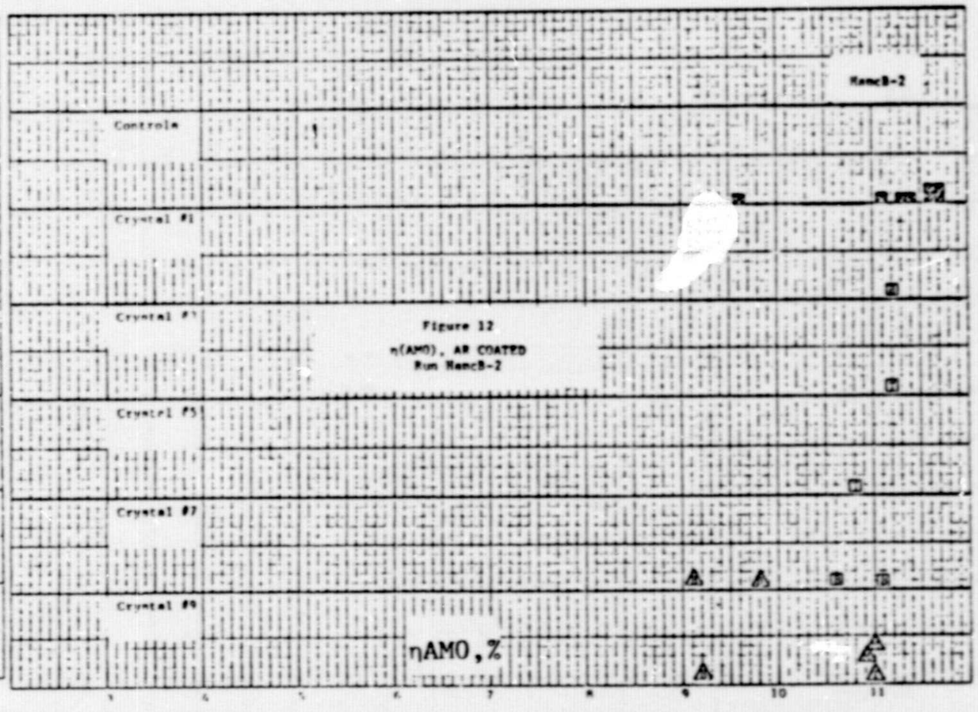

Figure 12

η(AMO), AR COATED Run HemB-2

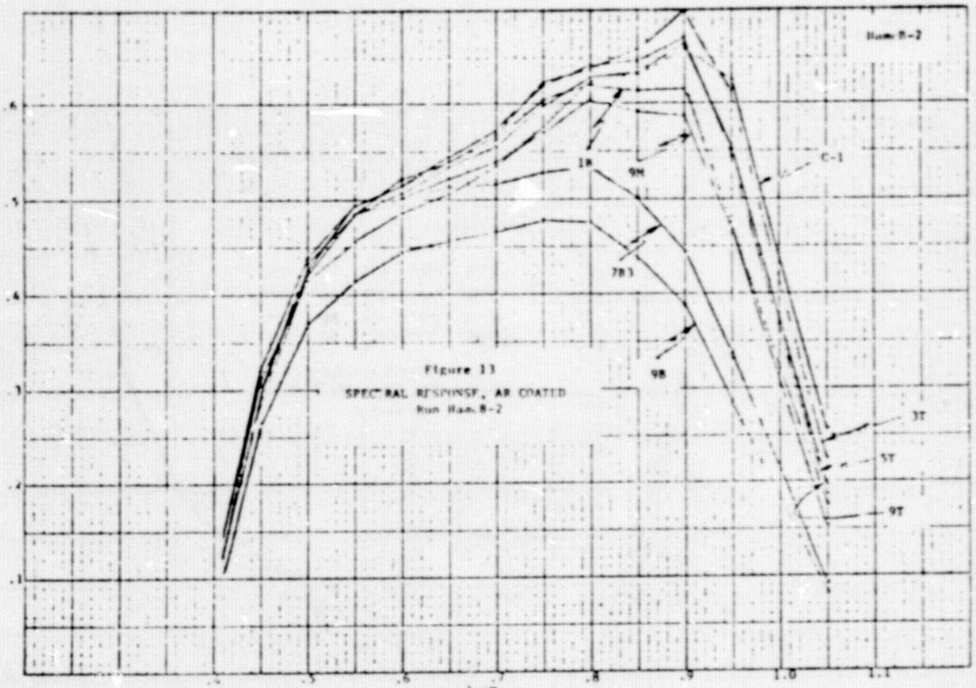

Figure 13
SPECTRAL RESPONSE, AR COATED
Run Ham B-2

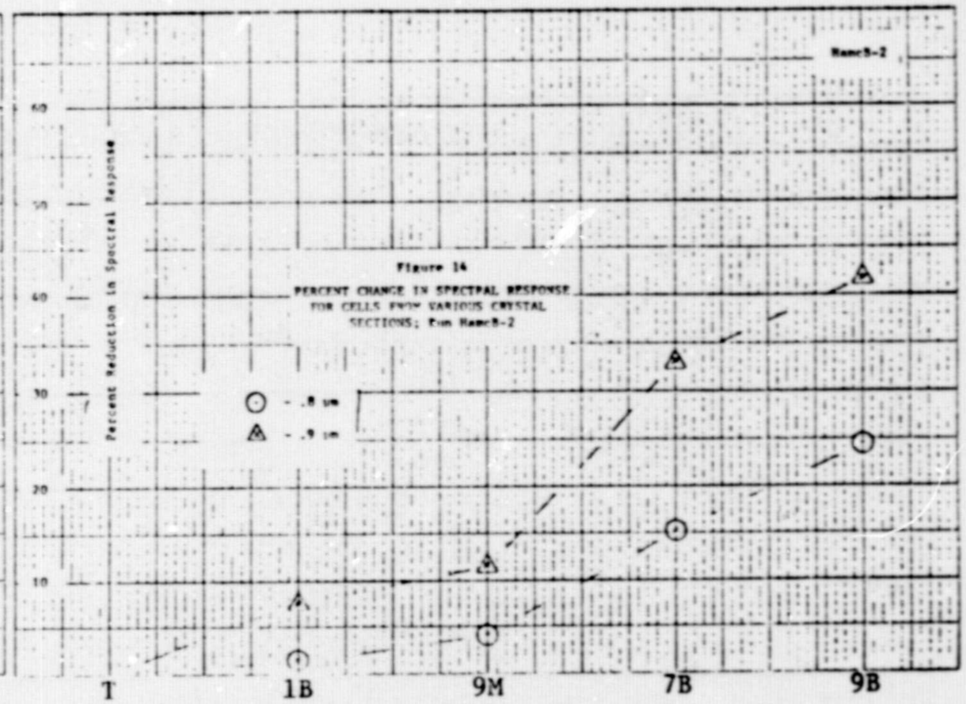

Figure 14
PERCENT CHANGE IN SPECTRAL RESPONSE
FOR CELLS FROM VARIOUS CRYSTAL
SECTIONS; Run Ham B-2

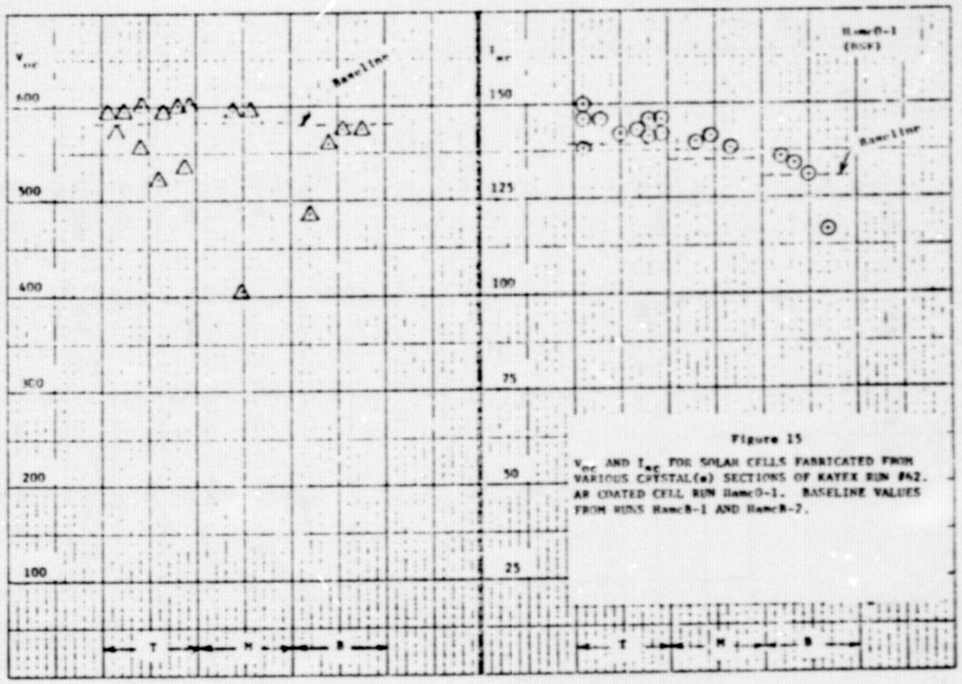

Figure 15
V_{oc} AND I_{sc} FOR SOLAR CELLS FABRICATED FROM VARIOUS CRYSTAL(s) SECTIONS OF KAYEX RUN #62. AR COATED CELL RUN Ham D-1. BASELINE VALUES FROM RUNS Ham B-1 AND Ham B-2.

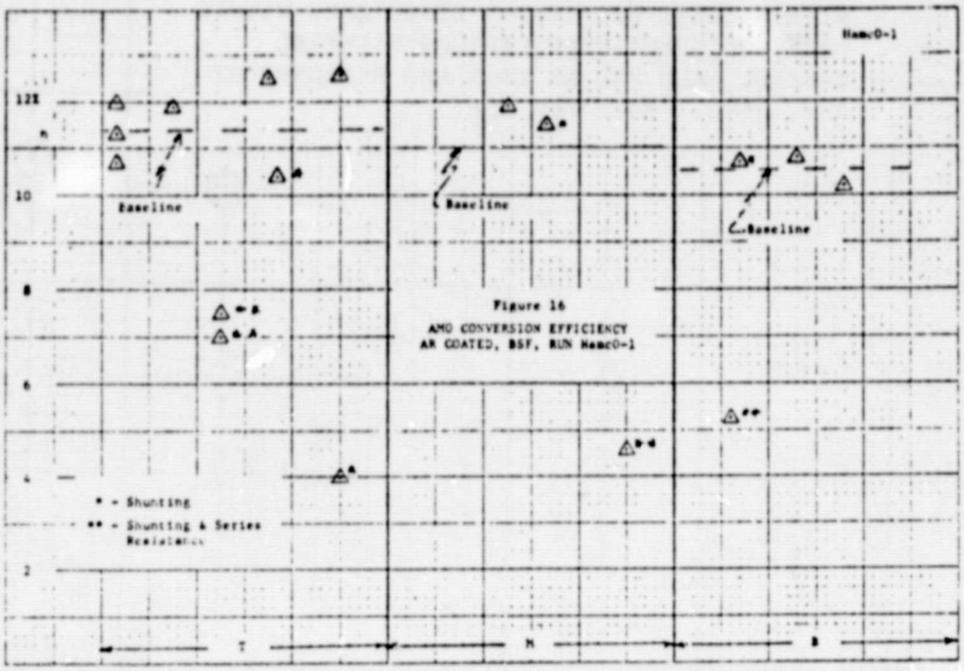

Figure 16

AMO CONVERSION EFFICIENCY
AR COATED, BSF, RUN HamcO-1

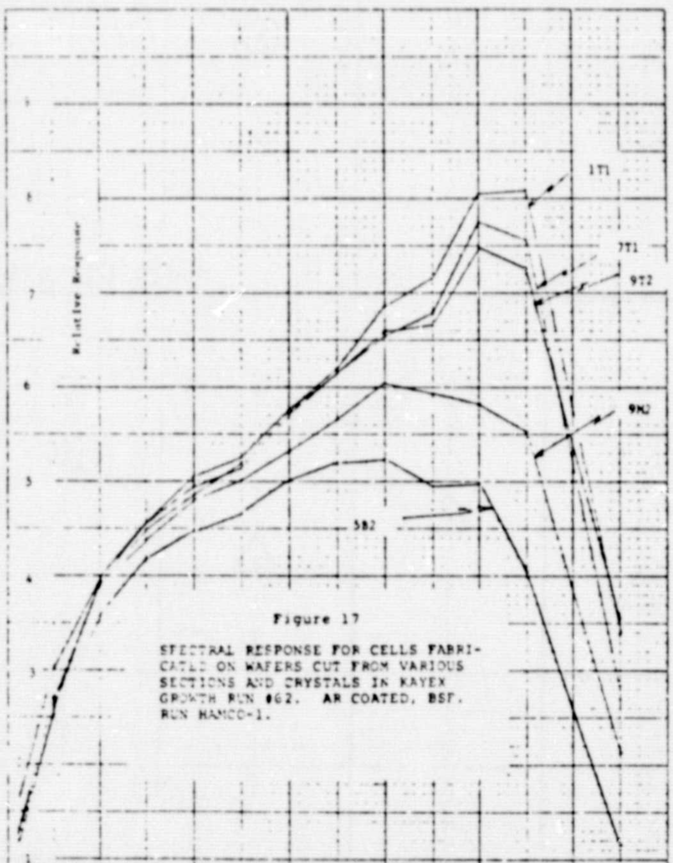

Figure 17

SPECTRAL RESPONSE FOR CELLS FABRICATED ON WAFERS CUT FROM VARIOUS SECTIONS AND CRYSTALS IN KAYEX GROWTH RUN #62. AR COATED, BSF. RUN HAMCO-1.

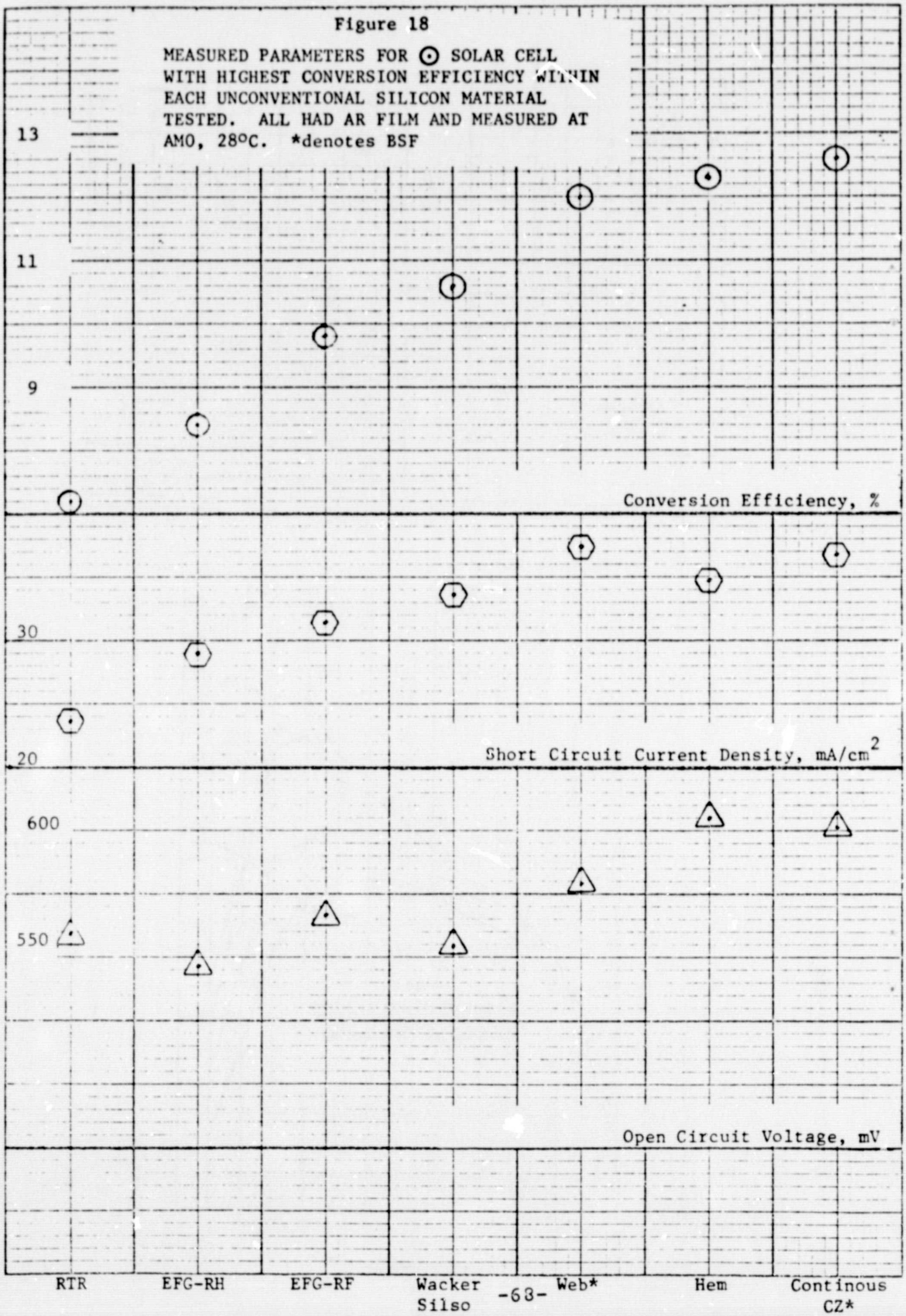

Figure 18

MEASURED PARAMETERS FOR ⊙ SOLAR CELL WITH HIGHEST CONVERSION EFFICIENCY WITHIN EACH UNCONVENTIONAL SILICON MATERIAL TESTED. ALL HAD AR FILM AND MEASURED AT AM0, 28°C. *denotes BSF